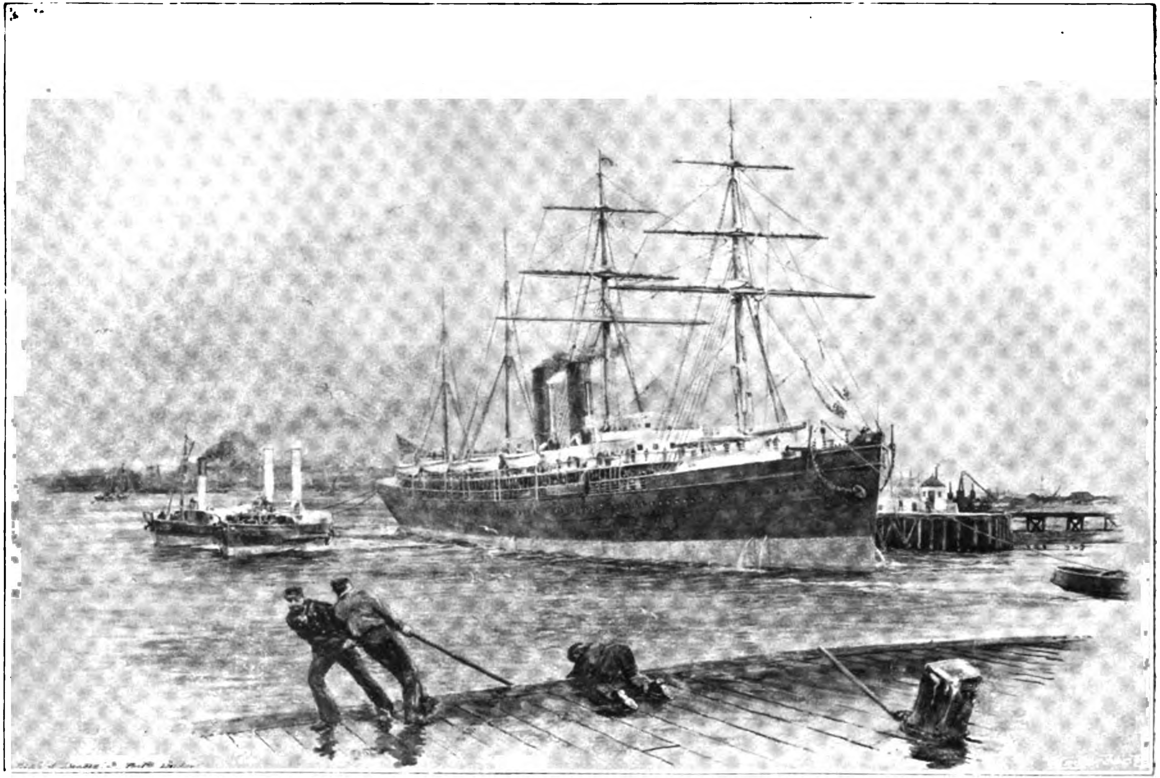
Journal

Iron and Steel Institute



The Orient Line R.M.S. "Ormuz."

From a Drawing by W. L. WYLLIE, A.R.A.

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IRON AND STEEL INSTITUTE

V

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OF THE

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EDITED BY

BENNETT H. BROUGH

SECRETARY

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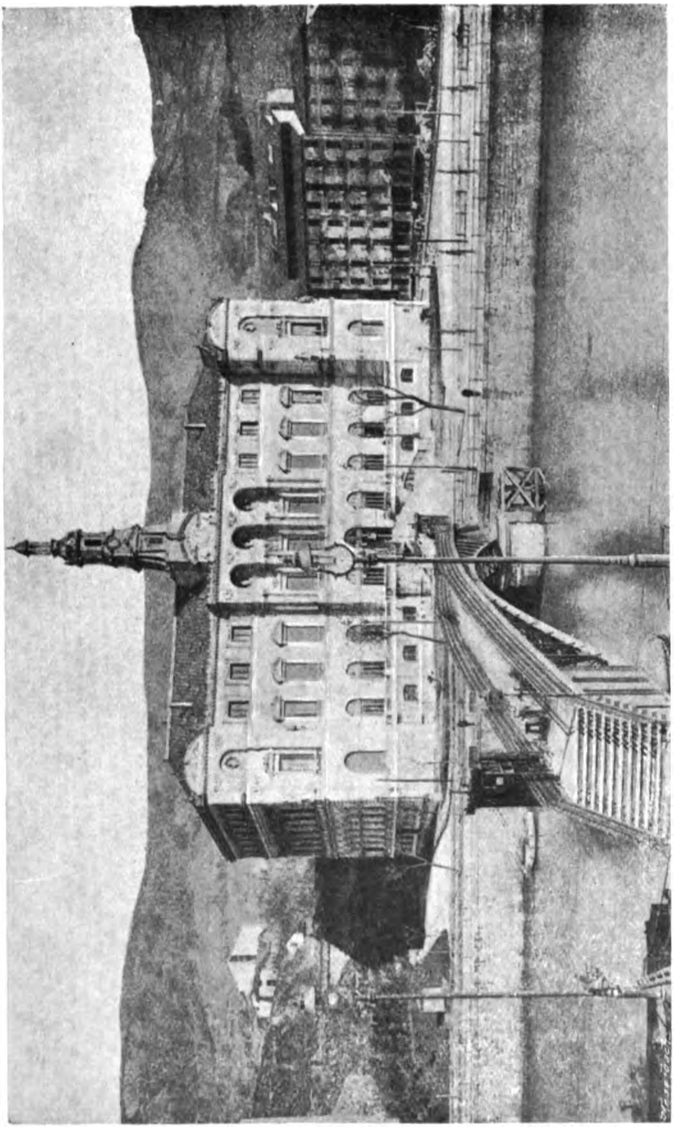


Bilbao Town-Hall.

THE

IRON AND STEEL INSTITUTE.

SECTION I.

MINUTES OF PROCEEDINGS.

SPANISH MEETING.

THE AUTUMN MEETING of the IRON AND STEEL INSTITUTE was held at the Provincial College, Bilbao, on Tuesday, September 1, 1896—Sir DAVID DALE, Bart., President, in the chair.

The ACTING ALCALDE of Bilbao, in gracefully welcoming the Institute to Spain, said that the task which had devolved upon him of addressing a few words to the members of the Iron and Steel Institute was a difficult one, as he knew full well how eloquently Don Emiliano de Olano would have expressed his cordial welcome. He was, however, extremely gratified at having the opportunity of addressing the members, and extending to them a hearty welcome in the name of the town of Bilbao. During the last few days the town had been honoured by the visit of musical artists of great fame; and now it was further honoured by the visit of an Association which embodied technical progress not only in England but throughout the world. He sincerely hoped that in visiting the works and mines of the district the members would find all that they expected to see, and that they would thenceforward remember that there was one town in the world that felt the deepest interest in all that concerned material, intellectual, and moral progress.

The PRESIDENT replied that the Council and members of the Institute highly appreciated the compliment conveyed in the official reception that had been accorded to them. That was probably the first occasion on which the great majority of the members had visited Bilbao; but no one of them was ignorant of the high historic rank and reputation of the city, or of the great prescience and wisdom with which it had recognised that, in modern conditions of civilisation, rank and importance could only be maintained by application with energy to industrial and commercial pursuits. In that respect Bilbao had become entitled to rank as one of the first commercial cities not only of Spain but of Western Europe. At the meeting on Wednesday, and more especially at the banquet on Thursday, it would be his pleasing duty to recognise more fully the arrangements that had been made for the entertainment and instruction of the members, and it was therefore unnecessary to enlarge upon the subject on the present occasion; they were not, however, on that account less sensible of the honour that had been done them. In behalf of his colleagues and himself he again thanked their friends very heartily for the official reception accorded to the members of the Institute.

The Minutes of the previous meeting were read by the Secretary and confirmed.

The PRESIDENT said he had to announce officially that of which the members had already become indirectly acquainted, viz., that the Council had selected Mr. E. P. Martin to succeed him in the presidential chair in May next. He perceived by the applause of the members that they had already anticipated what he was about to say—that he was sure that such a nomination would meet with hearty and universal approval.

Mr. E. P. MARTIN, Vice-President, begged leave to thank the members sincerely for the position in which they had placed him. While accepting it, he could not but feel that, though very honourable, it was also very onerous. He earnestly hoped that when his term of office had expired, he should be found to have given the members as much satisfaction as the distinguished Presidents who had preceded him.

The PRESIDENT said that, in accordance with the rules, it was his duty to announce the names of the retiring Vice-Presidents and members of the Council. The three Vice-Presidents who would retire in May next were Sir John Alleyne, Bart., Mr. James Riley, and Mr. Snelus. The members of Council retiring were Mr. W. Beardmore, Mr. R. A. Hadfield, Sir B. Hingley, Bart., Sir W. T. Lewis, Bart., and Mr. S. R. Platt. All those gentlemen, both Vice-Presidents and members of Council, were, he believed, eligible for re-election.

Mr. A. P. HEAD and Mr. JAMES I'ANSON were appointed scrutineers, and on the completion of their scrutiny reported that the following gentlemen had been duly elected members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Aznar, Luis M. de . .	Bilbao, Spain	William Whitwell, H. W. Hollis, Arthur Cooper.
Bratt, Ernst Morris .	Gothenburg, Sweden	H. Herbert Andrew, G. E. Hoyland, George Senior.
Cooper, Arthur Henry	North - Eastern Steel Works, Middlesbrough	John D. Ellis, A. Thielen, Percy C. Gilchrist.
Coppel, Gustav Gerhard	Sharrow Mount, Sheffield	Wm. F. Beardshaw, William Tozer, R. A. Hadfield
Davies, Henry . . .	Preston, Lancashire	George J. Snelus, Edw. P. Martin, J. E. Stead.
Dickinson, S. B. . .	Wolverhampton	S. Dickinson, William Roberts, Edw. P. Martin.
Dickinson, William Bowstead	10 Sandhill, Newcastle-upon-Tyne	William Whitwell, J. E. Stead, Edw. P. Martin.
Firth, William . . .	Water Lane, Leeds	Arthur Horsfield, Henry Steel, Jr., Leason Gray.
Harrop, Joseph . . .	Brondeg, Pontardulais, Glamorganshire	John R. Wright, W. Bevan, W. Bright.
Hay, Walter Robert .	20 Abchurch Lane, London, E.C.	Alex. S. Hay, Arthur Cooper, David Evans.
Herlenius, *Kapten* August	Storfors, Sweden	H. Herbert Andrew, G. E. Hoyland, George Senior.
Longbotham, Robert Hall	South Parade, Wakefield	Arthur Horsfield, A. T. Walker, Robert Sheard.
Marley, Thomas Edward George	Fleatham House, St. Bees, Cumberland	W. McCowan, Thos. Barlow-Massicks, George Scoular.
Martyn, George Rawlings	Dock Street, Newport, Monmouthshire	John R. Wright, Isaac Butler, Edw. P. Martin.
Miller, Robert Ernest	London Road Foundry, Edinburgh	Thomas Miller, John Cowan, Neil Robson.
Morris, Claude John .	Messrs. Rylands Brothers, Limited, Warrington	W. H. Bleckly, John J. Bleckly, Arthur Cooper.

Name.	Address.	Proposers.
Pease, Herbert Pike .	Normanby Iron Works, Middlesbrough	William Whitwell, Arthur Keen, James Riley.
Randles, John Scurrah	Stylecroft, Workington, Cumberland	George J. Snelus, Wm. Burnyeat, William McCowan.
Richards, Edward, Assoc. R.S.M.	Grove House, Hunslet, Leeds	David Evans, E. Windsor Richards, Edw. P. Martin.
Roberts, William Brook	Moorlands, 79, Clarendon Road, Leeds	Arthur Horsfield, Leason Gray, Richard Day.
Rosevere, Gerald . .	G. W. R. Co.'s Locomotive Works, Wolverhampton	Wm. Hutchinson, F. W. Harbord, Alfred Colley.
Schniewind, F., Ph.D.	Pittsburgh, Pennsylvania, U.S.A.	William Whitwell, Henry Phipps, Jr., F. N. Hoffstot.
Sota, Ramon de la . .	Bilbao, Spain	William Whitwell, H. W. Hollis, Arthur Cooper.
Thomas Ebenezer Rowland	King's Hill, Newport, Monmouthshire	J. H. R. Ritson, Isaac Butler, W. G. Dowden.

The President said that the first paper to be read was one by Don Pablo de Alzola on the Spanish Iron Industry. It was a paper of great importance, containing a large amount of statistical information, and giving a clear idea of the present condition of the Spanish iron industry. The full details given of the Altos Hornos Iron and Steel Works, and other works about to be visited, would render it of special value to the members; and the author's eminence as a civil engineer and director of the Altos Hornos Works could not fail to add to the weight of the views which it propounded.

The following paper was then read:—

THE IRON AND STEEL INDUSTRY OF SPAIN.

By El Excelentisimo Señor Don PABLO DE ALZOLA, C.E., Director of the Altos Hornos Company of Bilbao.

Iron Ore.

The object of this paper is to consider briefly the condition of the iron and steel industry in Spain, but it will be convenient to give first some idea of the iron ore deposits in the country, and to discuss the importance of the workings.

There are two important iron and steel districts in the Peninsula—that of Biscay, which derives its importance chiefly from the abundance, purity, and richness of its iron ores, and that of Asturias—where the extensive coalfields contain a large number of iron mines. The ores are, however, less rich, and much less pure than those of Biscay.

The total output of iron ore in Spain amounted in 1894 to 5,352,353 tons, and in 1895 to 5,514,399; but unfortunately only one-tenth of this large production is smelted in the country, for reasons which will be indicated subsequently, the remaining nine-tenths being exported. The provinces in which these minerals are worked, arranged in order of importance and of production, are shown in Table I.

From this table it will be seen that Biscay takes the first place with 80 per cent. of the total production, then follows the adjoining province of Santander with 10 per cent., the two together aggregating 90 per cent. of the total production of Spain.

The value given in Table I. is the estimated value of the ore at the quarry mouth before it has been handled for transport.

TABLE I.—*Results Obtained at the Spanish Iron Mines in* 1895.

Provinces.	Productive Concessions.		Area.			Workers.			Steam Engines.		Production.	
	Mines.	Quarries.	Hectares.	Ares.	Centiares.	Men.	Women.	Boys.	No.	Horse-Power.	Tons.	Value at Mine. Pesetas.
Biscay	106	52	1,953	57	97	7,891	62	190	11	216	4,574,724	17,690,940
Santander *	23	1	629	67	...	1,828	62	202	34	766	448,286	1,170,922
Murcia †	9	4	62	43	51	104	...	15	1	10	164,453	1,068,944
Seville	15	...	678	...	...	430	20	60	...	...	122,808	266,000
Almeria	14	1	141	18	61	882	...	480	...	...	99,511	398,046
Oviedo	48	4	1,308	12	2	291	8	92	..	...	59,253	118,506
Malaga	8	...	50	51	12	213	...	17	3	42	17,503	65,571
Navarre	10	...	99	15	44	84	...	16	1	5	12,474	59,750
Guipuzcoa	6	...	73	57	72	154	...	23	...	...	10,119	48,572
Granada	1	...	4	...	...	66	...	...	1	12	3,410	12,960
Ciudad Real	2	...	17	...	...	50	...	15	...	...	950	4,750
Teruel	2	...	60	...	...	6	...	...	...	...	450	3,600
Leon	4	...	80	...	...	10	..	..	...	...	354	6,018
Gerona	3	...	50	...	...	7	...	...	...	...	34	690
Alava	1	...	18	...	...	2	..	1	...	...	10	30
Totals . . .	252	62	5,225	23	39	12,018	152	1,111	51	1,051	5,514,339	20,915,299

* There are two hydraulic engines of 20 horse-power.

† These mines are termed argentiferous lead mines.

ORE MINED IN BISCAY.

The mining of iron ores and the smelting of them dates back to a very early period. The iron ore deposits of this province were known in the earliest times, more especially that of Somorrostro, the only one that has been worked continuously up to the present century. It is believed to be the one that the elder Pliny, who flourished in the first century of our era, noticed on the Cantabrian coast and mentioned in Chapter xxxiv., Book xliii. of his Natural History. His reference to this mine is as follows:—

"In the part of the Cantabrian coast which is washed by the Ocean, there rises a high and steep mountain, which marvellous to relate, is composed entirely of iron."

As far back as the tenth century, the incomparable soft ore of Somorrostro was shipped in the Bilbao river to Pasajes, San Sebastian, and other ports in Guipuzcoa, as well as to some parts in the adjoining country, principally St. Jean de Luz, Cape Breton, and Bayonne.

In short, the Biscayan ores were as important in ancient times as they are now, and as much sought after by foreigners.

The more important iron ore localities in Biscay, at which mining is now carried on, are eleven in number, namely: Somorrostro, Galdames, Ollargan, Sopuerta, Miravilla, Gueñes, Galdácano, Alonsótegui, Iturrigorri, El Morro, and Castrejana.

These mining districts are fully described in Mr. Gill's paper communicated to the present meeting.

ORES OF OTHER PROVINCES.

The extraction of iron ore on a large scale is not confined, as has been pointed out, to the province of Biscay, for it has of recent years been extended to Santander, where in 1895 a production of 448,286 tons was attained.

The districts in which mining was most extensively carried on in that year were that of Castro-Urdiales, thanks to the activity of the workings of the Setares Company, and of the Dicido Iron Ore Company, Limited. It is hoped with good reason, according to the chief mining-engineer of the province, that this output

will steadily increase on account of the construction of the mineral railway now in progress. It starts from the village of Onton for working the mines of that district, and there is also a railway connecting Miaño, Susa, and Otañez, places where there are numerous mine concessions which will thus be brought into communication with Bilbao and Santander.

In the Cabarga district various mines are in operation, amongst which are the workings of the Compañia de San Salvador and those worked by Mr. J. MacLennan, recently acquired by the Orconera Iron Ore Company, Limited, mines which, on account of the proximity to the point of embarkation and the endless chain and 9-kilometre railway available, are admirably situated from an economic point of view.

There exist, moreover, in connection with the concession of other mines, railways that traverse the greater portion of the district of Cabarga, and will also contribute to the development of the mining industry of this district. Amongst these are the railway from Bilbao to Santander, which will shortly be opened, and the prolongation of the Cantabrian Railway to connect with the line from Oviedo to Infiesto.

The manganiferous ores of the Sierra de Cartagena are also much in request abroad, and command very good prices in the English market. The production of these ores amounted in 1895 to 164,453 tons, and in 1894 to 162,196 tons.

With regard to the province of Seville, in which the output amounted to 122,808 tons, the principal iron range is included in that termed the Cerro del Hierro, which surrounds the towns of San Nicolas del Puerto and Constantina. The mines existing in this neighbourhood belong to William Baird & Company, Limited, and they have constructed a railway 17 kilometres in length connecting with the main line from Merida to Seville, by which the ore is carried to the latter port. The other iron range of this province, that of the Sierra del Agua, is 5 kilometres from Guadalcanal, and approximately at the same distance from the railway.

In the province of Almeria, the production in 1894 was 148,582 tons, which fell in 1895 to 99,511 tons, owing to several companies having suspended working. On the other hand a Bilbao firm, the Sierra Alhamilla Company, has begun working

on a large scale, and has constructed a mineral railway 36 kilometres in length, inclined planes, &c.

To conclude this brief summary of the Spanish iron ore deposits, a few words must be said about those of Asturias.

The Devonian formation, according to the researches of the Spanish mining-engineers, occupies an extensive central region, and contains important iron ore deposits in the form of beds, which varies in thickness from one to six metres, and supply the local ironworks. All the beds do not contain similar ore; indeed it varies in composition at different points in the same bed. The principal localities at which mines are in operation are:—

(1) Quiros, which supplies the blast-furnace of the same name; (2) Castañedo, which formerly supplied a part of the ore smelted in the Trubia blast-furnaces; (3) Llumeres, a deposit situated on the sea-shore in a good harbour, supplying large quantities of ore to the La Felguera Works of Messrs. Duro & Co.; and (4) the Sierra de Naranco, whose abundant mines, like that of Miéres, supply ore somewhat poor but at an extremely low price to the important ironworks of that name.

The yield of the Devonian ores at present worked varies from 40 to 51 per cent. They contain much silica, the proportion in those of Naranco amounting to 35 per cent., and in other places exceeding 40 per cent. They occur in the form of ferruginous sands; those of Quiros and Llumeres, although containing less silica, never contain less than 12 per cent. None of these ores are met with free from phosphorus, and they require as a rule a large quantity of limestone and of coke in the blast-furnace.

Among these deposits should be mentioned those acquired by the Miéres Works previously mentioned. Those that supply the Quiros blast-furnace, and those that belong to the "Sociedad Minas y Fundiciones de Santander y Quiros," which consist of six beds known for a length of 5 kilometres, of which one has the remarkable thickness of 10 metres.

The mining-engineers of the province have a very high opinion regarding these deposits, for, although the composition and richness are not constant, in the thickest and richest seams they can always maintain, by a simple method of working, an

average which, according to official information, represents a furnace yield of 45 to 48 per cent. They belong to the Devonian formation previously mentioned as traversing the province from north to south, from the Port of Ventana to the Bay of Llumeres. The richest ores contain 68 to 80 per cent. of ferric oxide, 12 to 25 per cent. of silica, 1 to 9 per cent. of alumina, and minute traces of lime, manganese, phosphorus, and sulphur.

In the province of Oviedo (Asturias) there were on December 31, 1895, according to the official statistics,* forty-eight productive mines and four concessions, with an area of 1308 hectares; and the production of iron ore in the year 1895 amounted to 59,253 tons. As has already been pointed out, there are two important iron-producing districts in Spain. Asturias has the disadvantage of inferior ores, and supplies its blast-furnaces with Biscay ores; but on the other hand it has the advantage of an abundant supply of fuel, and a careful study shows that the economic conditions of the two districts, for the production of iron and steel, are equally balanced.†

COALFIELDS.

The carboniferous formation of Asturias runs from east to west, and covers an area of 270,000 hectares. It presents a great variety of products, from anthracite, which occurs in the extreme west of the coalfield, down to the lignites, which are met with at the eastern extremity of the field. On the 31st of December 1895 there were in the province of Oviedo (Asturias) 328 productive mines and 117 concessions with an area of 16,147 hectares, giving in the year 1895 an output of 1,008,769 tons. In recent years important collieries have been acquired in Asturias by Bilbao capitalists, and worked with the object of importing into Bilbao fuel for the industries of the Nervion. The output which has been mentioned, though small in comparison with that of the colliery districts of the industrial nations of Europe, is not without importance for Spain; more especially

* *Estadistica Minera de España correspondiente al año* 1895, *formada y publicada por la Junta Superior Facultativa de Mineria.*

† See the interesting Memoir by the distinguished mining-engineer, Don Francisco Gascue, on the steel industry of the North of Spain.

TABLE II.—*Coal-Mining in Spain in the Year* 1895.

Provinces.	Productive Concessions.		Area.			Workmen.			Steam Engines.			Production.	
	Mines.	Quarries.	Hectares.	Ares.	Centi-ares.	Men.	Women.	Boys.	Number.	Horse-Power.	Tons.	Value at Pit Mouth. Pesetas.	Value per Ton. Pesetas.
Oviedo . .	328	117	16,146	99	61	7,454	·970	1,696	40	740	1,008,769	7,565,763	7.50
Cordova . .	17	10	1,288	64	43	1,847	46	180	34	1,077	277,347	2,609,903	9.41
Palencia . .	46	41	3,973	52	40	929	21	114	11	146	134,439	891,196	6.63
Ciudad Real .	6	...	329	...	..	564	40	16	9	131	111,175	555,874	5.00
Seville . .	20	8	1,080	59	06	535	25	40	21	1,063	107,403	969,849	9.03
Leon . .	31	5	2,593	72	86	518	2	...	8	343	58,418	292,092	5.00
Gerona * . .	3	1	307	23	48	507	...	23	4	150	41,404	356,072	8.60
Burgos . .	1	...	4	...	...	3	...	...	...	...	120	1,083	8.74
Totals .	452	182	25,723	71	84	12,357	1,104	2,069	127	3,650	1,739,075	13,241,832	

* There are two hydraulic engines of 23 horse-power.

when it is remembered that in a few years it has been doubled, and that it constantly increases, the output in 1895 having been 33,817 tons above that of the previous year. The production of mineral fuel in the Province of Oviedo (Asturias) is disposed of as follows:—

	Tons.
(1) Fuel consumed in the province	415,061
(2) Fuel shipped at Gijon by the Langreo railway and the Fomento wharfs, and at the port of Aviles	342,857
(3) Fuel carried to the interior of Spain, and acquired by the Northern Railway Co.	250,851
Total	1,008,769

As this quantity, 1,008,769 tons of coal, contains on an average 40 per cent. of lump or screened coal, and 60 per cent. of marketable small coal, it follows that it consists of 403,507 tons of the former class and 605,261 of the latter, and as in the washing of the raw small coal there is a loss of 25 per cent., the 605,261 tons of marketable small coal represents 756,576 tons of raw small coal, and consequently the quantity of coal raised from these mines during the year 1895 amounted to 1,160,083 tons.

The completion of the normal gauge railway from Ciaño to Santa Ana, which connects with the main line from Leon to Gijon, was effected in 1895; and the works carried out in the Aviles River, by the construction of a canal across the rock of Rechalda to the new port, will undoubtedly contribute to the development of the coal trade of Asturias.

Other important Ores Mined in Spain.

Besides iron ore, deposits of other metals are met with in Spain, and the following table shows the output of these ores during the year 1895:—

Ores.	Tons.	Value at the Mine. Pesetas.
Iron ore	5,514,339	20,915,299
Lead ore	124,195	10,261,561
Argentiferous lead ore . .	181,433	25,211,440
Copper ore	2,701,661	14 147,109
Zinc ore	54,109	1,850,037

It is to be regretted that so large a proportion of the raw materials are exported just as they are taken out of the earth, or with very slight changes, without conferring on the country the great benefits that would be derived from the successive transformations requisite to convert the ore into machines, ships, structural ironwork, and the various manufactured articles that are sent to Spain from foreign countries.

Of iron ore there was smelted in the country only 483,042 tons during the year 1895, an amount less than that treated during the previous year owing to the La Vizcaya having shut down one of its three blast-furnaces in the year 1895. This has again been put in blast in 1896. The ore smelted in the Spanish works in 1894 amounted to 566,050 tons. Of lead ore there was smelted in the country, 111,412 tons, yielding 76,808 tons of metallic lead; and 192,248 tons of argentiferous lead ore, which gave a product of 83,978 tons.

Refined silver obtained amounted to 58,546 kilogrammes in 1895, and to 192,745 kilogrammes in 1894. Of copper ore there was smelted 1,325,186 tons in 1895, yielding 7 tons of refined copper, 31,725 tons of burnt ore, and 5756 tons of copper mattes. Of zinc ore, 14,448 tons yielded 3149 tons of ingots, and 2487 tons of sheet zinc.

History of the Manufacture of Iron in Spain.

Reference has already been made to the exportation which took place during the tenth century of soft ore from Somorrostro, but at the same time that Biscay exported to foreign countries a part of its ores, a not inconsiderable quantity was smelted in the country, in forges situated in forests near streams, all the work being done by hand. Iron worked there acquired great renown for its quality, and it was sent not only to several Spanish provinces, but also to France, England, and the Netherlands.

In the middle of the fifteenth century there were no reducing hearths employing hand labour as motive power remaining in the forests, all having been removed to the banks of the rivers in order to utilise the falls of water, either directly for the blast or by means of water-wheels for driving the hammers and the leather bellows. At the end of the seventeenth century water-

wheels were employed to drive the hammers, and the wheels began to be used for working the bellows, which by degrees replaced the trompe, but up to that time no essential modification had been introduced in the process employed for the direct extraction of iron from its ores.

At the beginning of the sixteenth century there were in Biscay more than 80 *ferrerias* with a production in round numbers of 80,000 cwt., and at the end of the same century there were in Biscay and Guipuzcoa 300, each of which produced on an average 1000 cwt. of iron and steel per annum, making a total of 300,000 cwt. A third of this production was employed in different works, chiefly in shipbuilding; another third was converted into tools, artillery, fire-arms, nails, and various manufactured articles; and the remaining third was exported.

Shipbuilding acquired great importance in these provinces in the second half of the sixteenth century, for, according to writers of the time, there were in Spain in 1580 more than a thousand vessels. From Biscay alone more than 200 were engaged in the fisheries off the coasts of Newfoundland, and from Galicia, Asturias, and Santander, 200 traded with Flanders, France, and England in different kinds of merchandise.

In the second half of the seventeenth century there were in Biscay about 200 reducing hearths, of which more than 100 were in regular operation. The period of their greatest activity was from the second half of the seventeenth century to the end of the eighteenth, and this activity contributed largely to the great naval armaments of that age. The iron produced in these provinces acquired great renown for its superior quality, and from them was obtained all the material necessary for the construction and armament of the Spanish war and merchant vessels.

In Lierganes and the Cavada, at a short distance from the Guarnizo and Santoña docks, ordnance works were situated. Navarre and Guipuzcoa supplied the shells, bullets, and grape-shot for the Spanish artillery, whilst weapons and fire-arms were manufactured in Tolosa and Placencia. In the province of Guipuzcoa there were 18 manufactories of ships' anchors, the products being exported to Portugal, France, and England. In 1785 the Spanish naval authorities contracted to supply 407 to the state arsenals of two of these countries, and from this district

was sent also all the iron necessary for the construction and armament of ships of war.

Henry Cort's celebrated invention for the manufacture of iron by the indirect process, which was published in England in 1784, caused a revolution in the iron and steel trade, the effects of which were felt in Spain.

The first blast-furnace built in the Peninsula was erected at Marbella (Malaga) in 1832, and in 1849 blast-furnaces were built at Bilbao, at Santa Ana de Bolueta. The attention excited by these works was very great, but nevertheless the general introduction of blast-furnaces into Biscay took place slowly. Eventually, however, the large number of reducing hearths that existed in the Basque-Navarre districts disappeared, as might be expected, for the excessive consumption of fuel, the great cost of manual labour, and the high price consequently required for the wrought iron obtained by the direct process, could only conduce to their abandonment.

Before, however, blast-furnaces were regularly established in Spain, there was a transition period in which the metallic sponge furnaces were used, eight furnaces of the Chenot type having been constructed in 1859 at the Nuestra Señora del Carmen Works at Baracaldo, and eight other of the Tourangin modification in the following year, under the direction of the inventor, in seven different works in Biscay. The results obtained with both processes were, however, very inferior to those obtained by the use of blast-furnaces as a basis for the production of wrought iron. Of these blast-furnaces the few that were first constructed were mostly of small dimensions, and employed charcoal as fuel. For many years matters went on in this way, no regard being paid to the progress achieved by other nations.

Advancement of the Iron and Steel Industries

During this period of inaction in Spain, progress had been made with gigantic strides abroad. Men of science pursued with great energy the search for more logical and rational processes than those then in use for the production of steel. The first intimation to the public of the satisfactory results achieved by Bessemer in his researches for this purpose was, as is well known,

that contained in the celebrated paper read at the Cheltenham meeting of the British Association in 1856. At first the process met with the greatest success in Sweden, for converting by decarburisation pig iron into steel.

Experiments made in 1865 on a large scale by Martin, at Sireul near Paris, to obtain cast steel in reverberatory furnaces by the solution of wrought iron in a bath of molten iron, were also crowned with complete success by the employment of Siemens' regenerators.

The application of the processes discovered by these illustrious inventors led to a radical change in the conditions of the steel trade, but the mistaken political economy of the Spanish governments, foreign invasions, and fratricidal strife retarded for a long time the industrial development of Spain.

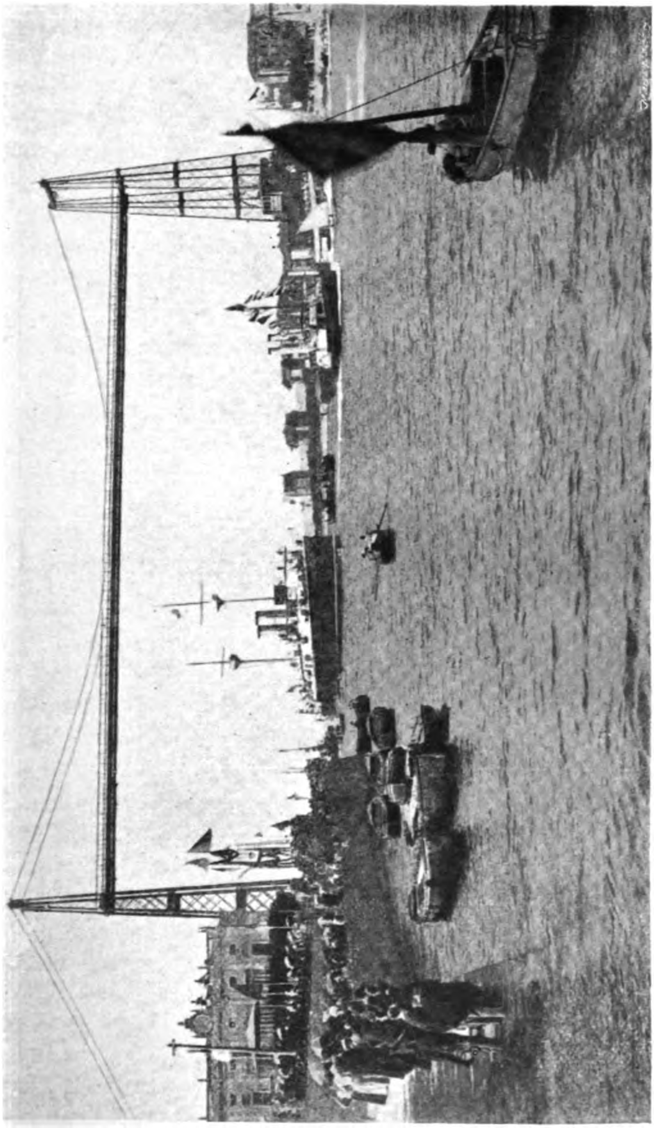
At the conclusion of the second Civil War, with which the country was afflicted from 1872 to 1876, during which Bilbao suffered a siege of five months, the Biscayans hastened to recover the ground lost. This is shown by the installation of the great works of Biscay, thoroughly abreast of modern progress, which was due, not to the beneficent action of the Spanish Legislation in the matter, but to the advantage taken of a casual circumstance. The discovery of the Bessemer and Siemens-Martin processes effected a complete revolution in the steel trade, and caused a considerable increase in the production, and a greater consumption of the raw materials required.

The new method of manufacture necessitated selected ores, very pure, and completely free from phosphorus. These conditions answered exactly to those of this district, and created an active demand for Spanish ore, the exports of which, as has been pointed out, exceed four million tons a year.

Now, however, the spirit of enterprise and of progress of the Biscayans has been the cause of a portion of the advantages derived from the working of the mines being diverted into undertakings destined to increase the riches of the country, by the installation of works for the production on a large scale of all kinds of iron, and more especially of modern steel.

At the end of the year 1882, serious attention was devoted to the necessity of establishing, on the banks of the Nervion, works for the production of iron and steel, equipped with the most

PLATE III.



Bridge between Las Arenas and Portugalete.

recent improvement. Two important companies were formed, each with Spanish capital of twelve and a half million pesetas. The first, named the "Sociedad de Metalurgia y Construcciones La Vizcaya," acquired for this purpose the marshes of Sestao, whilst the second, with the title of "Sociedad de Altos Hornos y Fábricas de Hierro y Acero de Bilbao," as a basis of operations purchased the old ironworks, "Nuestra Señora del Carmen," belonging to Messrs. Ibarra & Co.

In order to implant on Spanish soil the improvements in the steel industry, it was considered best to have recourse to the great industrial centres of Europe, the United Kingdom, and Belgium, with the object of benefiting by the experience of those countries in the manufacture of iron and steel. Consequently the works of the Sociedad de Altos Hornos were designed by the distinguished engineer and metallurgist, Mr. E. Windsor Richards, whilst the design for the Vizcaya Works was entrusted to the eminent establishment of Cockerill in Seraing.

Principal Works.

1. *Sociedad de Altos Hornos y Fábricas de Hierro y Acero de Bilbao.*

This company was formed on December 2nd, 1882, with a capital of twelve and a half million pesetas in 25,000 shares of 500 pesetas, with 90 per cent. paid up. At the same time 25,000 debentures were issued with a nominal value of 12,500,000 pesetas with 3 per cent. interest at a price of 60 per cent., redeemable in 50 years. At the 1st of January 1896, the total of debentures redeemed since the date mentioned was 3460. There were created 1250 founders' shares issued *pro rata* to the original shareholders as compensation for the trouble and expense caused by the floating of the company. These share in the profits after a dividend of 7 per cent. has been paid on the ordinary shares.

On its formation the Company purchased from Messrs. Ibarra and Co. their two ironworks, with all the plant. One of these works, termed the "Merced," is situated in Guriezo, in the province of Santander, and the other, termed the "Carmen," at

Baracaldo, at the confluence of the rivers Nervion and Galindo, five miles from Bilbao. The first works were confined to the production of cold-blast charcoal pig iron. The iron was of excellent quality, and the increasing requirements of consumption, and the difficulties of transport, induced the then proprietors, Messrs. Ibarra & Co., to seek another site which would completely satisfy the requirements, and they selected that occupied by the Carmen Works at Baracaldo. This covers an area of 116,500 square metres, with 500 linear metres of wharfs belonging to it, and 400 more at Portu, which is situated almost at the centre of the ground occupied by the works.

At the present time there are in operation at the Carmen Works three blast-furnaces, with a daily capacity of 300 tons of pig iron. The greater portion of this production is employed (1) for the manufacture of sheet iron, which is highly esteemed in the Spanish and foreign markets; (2) for castings for engines, structural ironwork, and various other applications; (3) for the manufacture of open-hearth and Bessemer steel, this being the only company in Spain making Bessemer steel; and lastly, (4) the remainder is sold in the Spanish and foreign markets.

For supplying blast, there are four blowing-engines, three vertical and one horizontal, representing an aggregate of 2000 horse-power. The hot-blast stoves are of the Cowper type. The blast-furnace gases, besides heating these stoves, serve as fuel for twenty-six boilers, capable of producing 3000 horse-power. Ore and limestone are brought from the mines to the works by railway, and they can be delivered with equal economy from the river Nervion. Coke and coal are discharged with great facility by means of five hydraulic cranes, and piers on to which the buckets loaded in the vessel's hold are lifted and run to the stock piles near the furnaces.

In a spacious hall, situated near the blast-furnaces, fourteen puddling furnaces are placed, with two hammers and the corresponding cogging-mill. There are also six rolling mills, with ten reheating furnaces. Of these rolling mills, three are intended for rolling merchant iron up to 14 centimetres, one for plates 2 to 5 millimetres, and the other, a universal mill, up to 500 millimetres, and 5 millimetres thick; and, lastly, another for rolling

wire rods of 5 to 7 millimetres. The plant also comprises two saws for cutting hot, three shears for cutting cold, a piling shop, and a workshop with eleven roll turning-lathes.

The Bessemer shop is of the American type. It is installed in a large low building which contains two converters. It can hold three, each capable of converting 9 to 10 tons of pig iron into steel in one operation, and there are on an average 16 blows per day of 12 working hours. These large converters are erected at a suitable height for them to revolve completely, which is effected by means of steam engines attached to the standards. In order to charge the converters with fluid metal brought from the blast-furnaces, to empty the contents of the converters into the ingot moulds when the blow is finished, and to lift out the ingots, hydraulic power is used, two elevators and three cranes being employed, and their movements, as well as those of the steam engines for tipping the converters, are regulated from a central platform in the same building. The blast for the converters is obtained from two blowing engines.

Below the converting house, there is an open-hearth furnace capable of producing 11 tons at each operation, as many as 18 heats having been obtained per week.

Adjoining this building are the stores of firebricks, tuyeres, and of other refractory materials, the grinding mills and a building with three double stoves for drying the bottoms, a small gas-producer for heating the ladles, two forges, and a hammer for tests and urgent repairs. At the level of the converters there are three cupolas for melting iron in admixture with the requisite quantity of ferro-manganese, in order to obtain the desired quality of Bessemer steel. In the same building there are two large cupolas for melting iron for the converters in the event of failure of the direct supply from the blast-furnaces.

The new steel rolling-mill is situated in a spacious building, and comprises three reheating furnaces working with forced draught, and two reheating furnaces of the Siemens-Martin type, with Wilson gas-producers and regenerators. In the central hall are placed the two reversing engines driving the rolls; the first of 2000 horse-power for the roughing rolls, and the other of 8000 horse-power, placed between the mill for ordinary sections and the plate mill. The rolls are supplied with cranes, shears,

and hot saw, large cold plate shears, a straightening machine, and two large roll lathes.

As a continuation of this building, and separated from it by the cooling floors, there are two other buildings in which are placed the presses, and planing, drilling, and punching machines for finishing the rails.

Another important department of these works is the building intended for testing. On the bottom floor there are placed all the machines requisite for the mechanical tests specified by the government for material for building war-ships, by the railway companies, and by private individuals who wish the material they have ordered to be similarly tested. On the same floor there is installed the electric lighting station for the works and its dependencies, and on the upper floor is a chemical laboratory as complete as can be desired, for the analysis of the various raw materials and products.

The necessity of attending promptly to the maintenance of the plant compelled the Company to instal a forge, foundry, and fitting-shop, which, although begun on a modest scale, have been so greatly developed that they not only fulfil the object for which they were started, but also enable the Company to accept profitable orders. This has notably been the case with railway appliances installed near Amorebieta by the Guernica railway, and that installed at Zorroza by the Bilbao-Portugalete railway, as well as metal roofs for important buildings, such as those of the Executive, Exchange, Library, and National Museums of Madrid. This workshop is also devoted to the construction of stationary boilers, some of which have been installed in the Company's works. In the fitting-shop some machines and steam engines have been made, the castings and forgings being made at the works. (See Plate IV.*)

The manufactured products find a ready sale in the Spanish markets, and the quality of the steel, both open-hearth and Bessemer, compares favourably with similar products manufactured abroad. The open-hearth steel plates and the bars of various sections used in building war-ships have answered all the tests demanded, so that as regards shipbuilding the

* Kindly lent, together with Plates XVII. and XXIII., by the publisher of the *Engineer*.

Spanish Government need no longer have recourse to foreign material.

The producing capacity of this establishment when in regular work may be taken to be 100,000 tons of pig iron, which yields—

12,000 tons of puddled iron.
15,000 tons of steel of various sections.
6,000 tons of plates.
45,000 tons of rails and bars.
6,000 tons of castings.
3,000 tons of bridges, roofs, and boilers.
1,000 tons of machinery.

The ores and limestone required by the works are brought by railway, and if necessary they could also be brought by river and unloaded at the wharfs at the works, the supply of Spanish and foreign coal being brought by river. The works being connected with all the Spanish railways, coal can be obtained from the interior of Spain, and at the present time the supply of fire-clay is obtained by these means. The facilities for exporting its products are the same as those for importing the raw materials. Owing to the limited space for depositing the slags, it has been found necessary to build a wooden pier and to obtain a steam hopper barge to carry these materials out to sea.

The number of workmen employed at these works amounts to 3000.

Under the patronage of the Company there have been formed (1) a benevolent society to assist invalid workmen and to maintain schools for their children; (2) a savings bank; and (3) a co-operative society for the officials and workmen where the necessaries of life can be obtained in the best possible conditions as regards quality and economy. Lastly, by the initiative of the Company and under the auspices of the Provincial Deputation and the Town Council of Baracaldo, a technical school has been inaugurated, the advantages of which may be obtained by the workmen free of charge.

2. *The Vizcaya Company.*

The Vizcaya Works with all its dependencies have been established at Sestao, on the banks of the Nervion, on what was

formerly a marsh, but that is now drained. The processes of loading and unloading take place at its wharfs on the river. It is ten kilometres distant from Bilbao, and is situated on the railway from Bilbao to Portugalete.

This Limited Liability Company was formed at Bilbao on the 22nd of September 1882, with a capital of 12,500,000 pesetas, divided into 25,000 shares of 500 pesetas each. In 1889, 12,500 debentures were issued to the value of 6,350,000 pesetas, the number unredeemed on January 1st of the current year being 11,800, of the value of 5,900,000 pesetas. At the Vizcaya Works there are in operation three blast-furnaces with a capacity of 360 cubic metres, capable of producing 120,000 tons of pig iron yearly. Two of these are provided with six Whitwell stoves each, and the third with three Cowper stoves. The four blowing engines, which supply 2100 cubic metres of air per minute, have an aggregate horse-power of 1900. Furnaces Nos. 1 and 2 were blown in, in June and December 1885 respectively, and No. 3 in July 1890.

The manufacture of coke, with recovery of by-products, began on the 9th of November 1888, and the plant comprises 144 Simon - Carvé's coke - ovens, producing annually 110,000 tons, and by-products, such as coal-tar, ammonia liquor, ammonium chloride, benzene, &c. The manufacture of steel is by the Robert and Siemens-Martin processes, three converters and four open-hearth furnaces being in operation. The Robert converters have a capacity of five tons, and can produce 120 tons each, while the open-hearth furnaces, two of which are provided with an acid lining, and the other two with a basic lining, are capable of producing 12 tons each. The open-hearth furnaces were put in operation on the 28th May 1889, and the first cast of Robert steel took place on the 4th February 1892.

These works also make puddled iron for rolling into merchant iron, the plant consisting of four puddling furnaces, one double gas-furnace of the Siemens type, with two of the type invented by Mr. Pradera, managing director of the works. The manufacture of puddled iron began on the 29th May 1891.

The rolling mills, which are intended chiefly for the manufacture of rails, sleepers, tires, and merchant iron of all kinds, began work on the 31st May 1889. At the present time

straightening rolls are being erected, these being greatly needed if the Spanish market is to be rendered independent of foreign manufactures. The principal installations comprise 8 hydraulic cranes, 1 double-acting steam-hammer of 3 tons, 1 blooming mill for puddled iron, 6 plate mills, 9 reheating furnaces of the Siemens, Pradera, and Bochum types, 43 steam boilers (furnishing 4000 horse-power), saws, shears, straightening machines, lathes, planing machines, and drilling machines. The works are also provided with foundries, fitting shops, forges, and testing machines. There are also within the works 11,000 metres of railway, with 7 locomotives, and a full equipment of trucks. The Company works its own mines, and others leased, in the Galdames district, whence it obtains 200,000 tons per annum, and employs for this purpose 1000 workmen. In the works themselves there are employed 1500 workmen. The executive staff comprises nine engineers. The Company has founded a benevolent society, a co-operative society, and maintains a hospital with two doctors on the staff, and a suitable number of assistants.

The Company has exhibited its products at various exhibitions, and has obtained awards at Antwerp in 1885, at Barcelona in 1888, and at Paris in 1889.

The annual production of the works comprises—

200,000 tons of iron ore.
100,000 tons of coke.
100,000 tons of pig iron.
25,000 tons of open-hearth and Robert steel.
6,000 tons of puddled iron.
25,000 tons of rolled iron and steel.

3. *The San Francisco Works.*

These works belong to Don José Maria Martinez de las Rivas, and are also situated at Sestao. They are confined exclusively to the production of coke pig iron, which is sold for the most part in Spain, the surplus being exported. The works comprise four blast-furnaces, but of these two only are in blast. There are also three batteries of coke-ovens, which produce the greater portion of the fuel required in the works, Asturian and English coal being employed for its production.

The present out-turn of the works consists of—

20,000 tons of coke.
36,000 tons of pig iron.

Don José M. de Martinez possesses a large area of ground near the river, and in 1889 he associated himself with the well-known constructor, Sir C. M. Palmer of Jarrow, in a contract with the State for building three cruisers of 7000 tons displacement each.

In an extremely short time all the necessary plant was erected, and hence were launched the *Infanta Maria Theresa*, *El Vizcaya*, and *El Admirante Oquendo*, which are without doubt some of the finest war-ships possessed by the Spanish Navy.

During the construction of these cruisers, the conjoint firm Rivas & Palmer was formed into a limited liability company under the name of "Astilleros del Nervion," by which name this important shipbuilding firm is still known.

4. *The Works of Asturias.*

Duro & Company.—This company, which is of considerable age, possesses iron and steel works in the defile known as La Felguera (by which name the works are also known), in the valley of Sama, in the centre of the Langreo coalfield, a situation which renders it possible to obtain coal under extremely economical conditions, from their own and from neighbouring mines. The Langreo railway and the Northern railway, with their branches to Ciaño and Soto del Rey, are connected at La Felguera, with the well-known ports of Gijon and Aviles.

The local ore contains phosphorus, and it is consequently necessary to mix it with ores obtained from the Bilbao mines, although in a small proportion.

At present there are in operation two blast-furnaces, which produce 30,000 tons per annum of pig iron, and two batteries of coke-ovens from which is obtained 15,000 tons of coke, which is used in the works. Steel is obtained in three open-hearth furnaces, and in order to obtain wrought iron twenty puddling furnaces are provided.

In the works there are two rolling mills for plates and large sections, another for small sections, and a universal mill for wide plates and for rolling all kinds of merchant iron, of which the bulk of the out-turn is composed.

The total production of the works is as follows:—

30,000 tons of coal.
15,000 tons of coke.
30,000 tons of pig iron.
7,000 tons of open-hearth steel.
22,000 tons of merchant iron.

Miéres.—This limited company has a capital of 2,000,000 pesetas, and is engaged in working numerous important collieries, and in the manufacture of iron and steel and structural material.

In the works at Miéres which are connected with the Northern railway, and which are consequently in communication with the interior of Spain, and with the ports of Gijon and Aviles, there are at the present time in operation two blast-furnaces, with a third undergoing repair; three batteries of coke-ovens; an open-hearth furnace of recent construction, and five rolling mills for blooms and merchant iron. There is also a well-equipped erecting shop for structural work, to which attention is chiefly devoted, and the bridges that have been made in this works for various highways and railways in the Peninsula are much appreciated.

The annual production of the works is as follows:—

200,000 tons of coal.
36,000 tons of coke.
24,000 tons of pig iron.
7,000 tons of open-hearth steel.
18,000 tons of merchant iron.

Moreda y Gijon.—This is a French limited liability company with registered offices in Paris, and a capital of 500,000 francs. At the works of the Company pig iron is made for use in the works for rolling small sections, for the market, and for wire and wire-nail manufacture.

The works comprise one blast-furnace, ten puddling furnaces, two rolling mills, and all the machinery requisite for making wire and wire nails.

The production is as follows:—

16,000 tons of pig iron.
6,000 tons of merchant iron.
4,000 tons of wire and wire nails.

The Moreda and Gijon works are situated within the latter town and close to the port. Local ores are used, somewhat phosphoric, mixed with Bilbao ores, and the charcoal and coke consumed are exclusively of Spanish origin.

5. *Other Works.*

Having described the principal Spanish ironworks, the author feels that it will not be out of place to refer briefly to other companies or undertakings which are designed for the further treatment of iron and steel, or are intimately connected with the manufacture of those metals.

Sociedad Material para ferro-carriles y construcciones (Barcelona).—This is a joint-stock company which has its works in the vicinity of Barcelona. Merchant iron obtained from scrap iron is worked up for the construction of bridges and roofs, and also for the construction of railway carriages and waggons. It is the only company in Spain engaged in this class of work.

Maquinista Terrestre y Maritima (Barcelona).—This is a joint-stock company, with a capital of 3,135,000 pesetas fully paid up. In addition to all kinds of machinery, it has constructed more than 300 metallic bridges and a large number of roofs. The works deal with all varieties of engineering construction, and have supplied the engines for most of the war-ships built in the State Arsenals. They have also supplied various locomotives for the railways from Langreo and Barcelona to Tarragona and France.

Civil Arsenal of Barcelona.—This is a joint-stock company, with a capital of 1,250,000 pesetas, engaged in shipbuilding and general engineering work, such as bridges, roofs, &c.

Sociedad Santa Ana de Bolueta (Bilbao).—This is a limited company, with ironworks in the vicinity of Bilbao. It has two charcoal blast-furnaces, and mills for rolling merchant iron.

Hijos de J. J. Jauregui (Amorebieta).—This firm possesses a charcoal blast-furnace, and rolls several sections of iron. Special attention is devoted to hammered iron, and high qualities, which form the speciality of the firm.

Alambres del Cadagua (Bilbao).—This is a joint-stock company, with a capital of 525,000 pesetas, devoted exclusively to the manufacture of wire, nails, &c.

Tubos Forjados (Bilbao).—This is a limited company, with a capital of 1,500,000 pesetas, devoted to the manufacture of wrought iron and steel pipes for gas and water, tubes for bedsteads, and other industrial purposes.

La Euskazia (Bilbao).—This is a limited company, with a capital of 500,000 pesetas. Its works are situated at Amorebieta (Biscay), and produce excellent castings and wood screws.

Aurrera (Bilbao).—This is a limited company, with a capital of 1,500,000 pesetas, devoted chiefly to the manufacture of cast iron pipes.

La Iberia (Bilbao).—This is a limited company, with a capital of 1,500,000 pesetas. Its chief manufacture consists of tin plates and of boxes made of that material.

Basconia (Bilbao).—This is a limited company, with a capital of 1,250,000 pesetas. Like the preceding, it is engaged in the manufacture of tin plate.

Talleres de Deusto (Bilbao).—This is a limited company, with a capital of 1,000,000 pesetas. Its chief manufactures are steel castings.

Talleres de Zorroza (Bilbao).—This is a limited company, with a capital of 1,000,000 pesetas, devoted to structural metal-work, foundry, and engineering work.

Vasco-Belga (Miravalles).—This is a limited company, with a capital of 1,000,000 pesetas. At its works at Miravalles all kinds of engineering work are made, including steam engines and railway waggons.

Hijos de Romualdo García (Bilbao).—The San Pedro works of this firm are situated at Elgoibar, in Guipuzcoa. They manufacture charcoal pig iron and open-hearth steel.

Viuda de Urigoitia é hija, Araya (Alava).—This firm owns ironworks, with two charcoal blast-furnaces, one of which is in blast, and two rolling mills.

José M. Quijano, Los Corrales (Santander).—This is a very important works, devoted to the manufacture of wire and wire nails.

La Maquinista Guipuzcoana (Beasain).—These works employ a 100 horse-power Girard engine and a 100 horse-power steam engine. They have a 350-kilogramme steel converter, a cupola, blowing engine, &c. In the foundry there are two rapid cupolas, each melting 4 tons an hour. In another building, flour-milling machinery is constructed, and in a covered hall there is an open-hearth furnace and two rolling mills. These works have turned out a large number of turbines, steam engines, Austro-Hungarian mills, and bridges. The manufacture of railway plant is contemplated.

There are other important engineering works in Guipuzcoa, in Catalonia, Andalusia, &c., besides the engineering shops of the railway companies.

The following figures show the total production of iron and steel in Spain, according to the official statistics for 1894:—

	Tons.
Pig iron	260,000
Wrought iron	120,000
Steel	70,000

Production of Pig Iron in various Countries.

In all well-regulated countries the governments have furthered the development of the iron and steel industry, since iron and steel take so prominent a position as the most striking indications of modern progress—both in public and private buildings; in stupendous bridges; in the rails which are always tending to increase in weight; in the engines driving the complicated machinery of the textile and manufacturing industries; in the enormous ironclads of the navy; in the rapid transatlantic steamers; and in the cannons of large calibre for coast defence, for fortresses, and for the navy. Moreover, the manufacture of iron and steel induces a considerable consumption of mineral fuel, and gives an impetus to mining operations, and necessitates the transport of large quantities of great weight and volume, and thus increases the traffic on the railways, ocean, rivers, and ports.

No other industry has done so much towards the development of the population and of the national power, and with such indisputable success.

The production of pig iron in various countries is shown in Table III., in which the figures represent thousands of tons for the last year of each decade. From this it is possible to judge with considerable certainty of the more or less rapid development of the metallurgy of iron in the different countries of the world.

TABLE III.

Countries.	1864.	1874.	1884.	1894.	Remarks.
United Kingdom	4,834	6,054	7,651	7,546	Maximum 8,458 in 1889.
Germany	905	1,906	3,600	5,380	Has increased regularly since 1874.
France	1,212	1,423	1,871	2,077	
Belgium	450	533	751	811	
Austria-Hungary	319	509	734	990	
Russia	301	380	510	1,314	
Sweden	284	328	430	463	
Spain	51	40	124	260	
United States	1,031	2,430	4,165	6,840	Maximum 9,304 in 1892.
The World	9,522	13,772	20,204	26,225	

This table shows that during the last thirty years the world's production of pig iron has increased from 9·5 million tons to 26·2 million tons, and that the increase in consumption presents a wide field of contest for all the countries endowed with raw material for their admission to the number of industrial countries. The most rapid development during the period under consideration took place in Germany and in the United States, where the production increased six times. Austria-Hungary has increased its production threefold, and Russia fourfold. All these countries have protective tariffs, and the last-named empire, like Spain, has still a scanty production for the number of inhabitants. Indeed, comparison with France, which is not one of the best developed countries metallurgically, shows that although less than half the quantity of ore raised in the Iberian Peninsula is mined in the adjoining republic, the pig iron produced is eight times as much.

In the United Kingdom a serious crisis has of late years been

experienced both in the iron trades and in the shipbuilding trades. The causes of this have been stated in presidential addresses to have been due chiefly to over-production, to limited investment, to lowering of prices, and to the great progress in machine construction made by various Continental nations.

The causes of the smaller production of iron and steel in Spain are, in the author's opinion, due chiefly to the defective industrial conditions in Spain. The consequences of such policy have been disastrous for Spain, for with 12,500 kilometres of railways in operation, it has not been possible to undertake, except as an experiment, the manufacture of locomotives, and the building of merchant vessels has also disappeared almost completely, owing to the employment of duty-free foreign material in the few steamers built in the Spanish shipyards. And it must not be imagined that the consumption in Spain is insignificant, for the annual imports of foreign rails from 1883 to 1892 averaged 30,514 tons, and the imports of manufactured iron and steel, machinery, and iron ships in 1891 amounted in value to 76·4 million pesetas, the greater portion of which entered exempt from duty. Consequently the indigenous production of pig iron is reduced, and the producers are obliged to export an appreciable quantity with the disadvantages inherent to universal competition with countries organised exclusively for producing cheaply and for invading all the markets.

Comparison between the Mining and Metallurgical Industries of Biscay.

From the facts given above, it is evident that of the iron ore mined in Spain, not more than one-tenth is converted into pig iron, the remainder being exported. As regards copper, the situation is even more unfavourable, for although Spain possesses the magnificent deposits of Rio Tinto, the native manufacture is confined to the rudimentary calcination necessary for obtaining the burnt ore (*cascara*), and almost all the raw material is handed over to other more fortunate countries, where it is converted into metal for use for machine construction, electrical engineering, and the decorative arts. In other words, in the richest country in Europe in cupriferous pyrites,

copper can be obtained only at a price so high that its use for manufacturing purposes is rendered impossible or greatly limited.

It is evident that if the orefield of Bilbao was very extensive, and of indefinite thickness, the fact that such enormous amounts of ore were raised and shipped so rapidly and improvidently would be immaterial; but as quite the contrary is the case, it is difficult to realise the pernicious influence that will be produced in the future of Biscay by the exhaustion of its ores. This is shown by the fact that countries provided with capital, spirit of enterprise, and business ability are called upon to further the prosperity of those countries more backward in the path of progress. Clearly, however, if, as in Spain, every possible facility is given to foreigners to acquire property, as is not the case in all countries, foreign capital should, at any rate, be directed to promoting the permanent good of the country rather than to conferring upon it a fugitive and ephemeral prosperity.

From 2 tons of ore valued at 18 pesetas, there is obtained 1 ton of pig iron, the price of which is 64 pesetas. If this is converted into rails, it sells at 140 pesetas; rolled into steel plates it increases in price to 210 pesetas; forged into axles, &c., it increases to 700 pesetas; and if it is converted into engines and boilers it increases to 1200 pesetas per ton, and to 1500 in locomotives and marine engines. The evident result is that if the greater portion of the ore is sold for the insignificant price of 9 pesetas, Spain imitates Esau in selling his birthright for a mess of pottage.

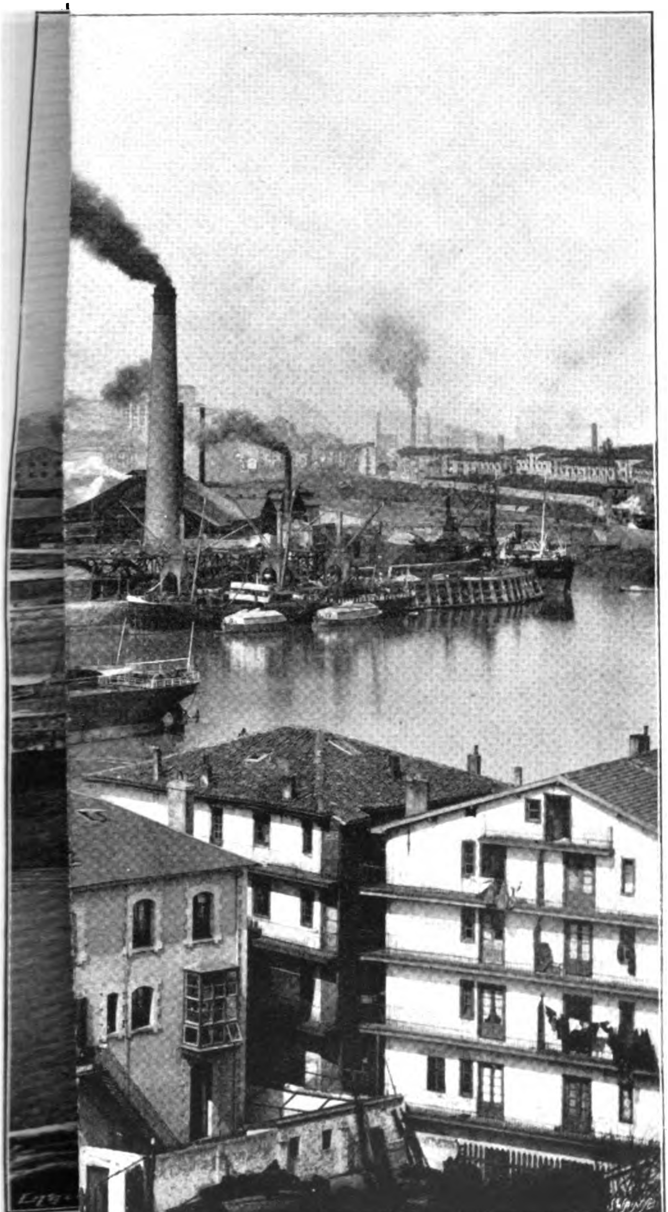
It would be idle to deny that fortunes have been made out of mining in Biscay, and, in view of the fact that the commercial management of manufacturing concerns is much more difficult, and that the resulting profits to the capitalists are very moderate, it is natural that mining should be preferred to metallurgy. This, however, as has already been pointed out, is due to the defective economic organisation in Spain.

In short, in Spain matters have been arranged in a way best adapted to stimulate the extraction of raw material, and consequently greater facilities have been given for exporting ore than for manufacturing iron.

If matters had been arranged differently, by stimulating in Biscay the manufacture of steel, and by imposing some restrictions on the export of ores, the future prosperity of the country would be assured. Foreign capital which hitherto, as a general rule, has been devoted to undertakings on small estates, would be found to be valuable for the development of industry, as has been the successful practice in Russia and in other countries, and in this way foreigners would become the instructors and guides of Spaniards in the beneficent work of national regeneration, and by uniting the metallurgical and iron trades with that of mining, Spain would have been able to compete with advantage in a share of the world's commerce.

It has been asserted that in the southern districts of Europe there is no aptitude in the race for manufacturing affairs. This is, however, a common error. In the first place, both Italy and Spain had an important trade up to the sixteenth century. Moreover, Louis XIV. stated that the French people were composed of idlers and vagabonds, and the measures dictated by Colbert sufficed to transform them into active and laborious members of society. A similar regeneration may be observed in Catalonia, where the annual production of cotton goods reaches two hundred million pesetas, and the modern portion of Barcelona is as stately as any other European city which is not a capital of a country. The ineptitude attributed twenty-five years ago to Spanish engineers in the matter of constructing and working railways has ceased, facts having shown the fallacy of the assertion. The similar prejudice, still existing in official circles, which deprives the national trade of the building of war-ships for protecting the mercantile marine, is also disappearing in face of the magnificent progress made in the Italian shipyards, and of the war-ships built in Spain. There can be no doubt of the great skill, cheap producing power, and superiority of the English in this class of work. Having regard, however, to the weakening action on nations caused by the acquisition of all kinds of manufactured goods in foreign countries, it is natural that the possessors of raw materials should aspire to enter into the concert of civilised powers, being guided by the example afforded by the rapid progress of the German Empire, whose industrial development is also of recent creation.

PLATE IV.



OS.

DISCUSSION.

Sir LOWTHIAN BELL, Bart., Past-President, said he had been appealed to by the President to say a few words on the paper just read. Unfortunately, although he had been in Bilbao on a previous occasion, that previous occasion was about the year 1870. At that time he found that a certain development of the mines had been made, but everything was on the rudest and crudest footing. The whole of the ore was brought down by very primitive carts, drawn by very primitive locomotives—viz., the oxen of the country. There were certainly one or two blast-furnaces to be seen. After an interval of twenty-five years, he now returned to find that, in the meantime, a magician had been at work in that part of the world, or rather a host of magicians, for that which had been bare rocks or smiling country had become covered with works of great extent, and he of course knew enough of them by reading to be aware of the character of the extensions that had been going on during the interval. He had come to Bilbao with very high expectations as to the position of the industry of the country; but however high they might be, he had no doubt that they would be amply confirmed by what he should have the opportunity of seeing during the visit of the Institute. He would only repeat what had been said before, how deeply the members were indebted to the gentlemen who, with the utmost openness and candour, had prepared for them accounts of everything that had been done, so that even if they did not go from Bilbao happier men, they would return from it wiser men than they were when they started from home. It was quite unnecessary to enter into any criticism of the paper. Its contents spoke for themselves; and he was quite sure every one who read it could not fail to recognise the extreme ability of the author in his treatment of his subject.

Mr. AINSWORTH asked whether there was not some mistake in the statement that at the Vizcaya Works each of the three blast-furnaces in operation was capable of producing 120,000 tons of pig iron per annum.

The SECRETARY said that the output stated was from the three blast-furnaces, not from each of them. The error in the proof would be corrected before the paper was printed in the Proceedings.

CORRESPONDENCE.

Mr. H. G. GRAVES thought that, in connection with the present export duties on iron ore, and the remarks made on them by the author, it was very interesting to note the stringent laws that were in force in the Basque provinces during the last century. These laws absolutely prohibited the export of iron ore, and they recalled the similar laws of our own country which were passed to prevent the export of sheep and other *raw* products. The section of the *Fueros de Vizcaya* dealing especially with iron ore (of which a translation is given below), is one of the collection reprinted in 1771 from the laws as they were revised in 1526 by a representative committee of the inhabitants:—

Law XVII. That no *vena* shall be exported to foreign kingdoms. Furthermore they say: that they have as a statute right and custom, and they establish as law that no native nor alien in the lordship of Biscay, or in all the kingdom of Spain or abroad, shall export from the said lordship *vena*, or any other mineral for the making of iron or steel, under the penalty that the person exporting it shall have the moiety of his property confiscated, and shall be banished in perpetuity; and the ship, boat, or other vessel whatsoever in which it was exported, and the merchandise carried in it, shall be confiscated, and all that and the said moiety of property shall be divided, one-third for the repair of the roads of the said lordship, another third for the informer, and the remaining third for the justice that convicts.

There were in this code many other enactments which dealt directly or indirectly with the question of iron ore and iron-works. Of these the most important was chapter xxviii., which dealt with the maintenance of iron-works, the weights used, and the ore. The first section gave the iron-works the preference in the purchase of charcoal, and directed how it was to be

measured; the second showed who could weigh and buy iron, and prescribed that it must be of good quality; the third gave the size of standard weights, whilst the last controlled the manner of sale of iron and steel. The penalties for any infringement of these laws ranged from six hundred to ten thousand maravedis, and were divided half to the informer and half for the repair of the roads.

The PRESIDENT said that Don Pablo would no doubt understand that the absence of any inquiry or discussion was attributable to the completeness and clearness of the paper which he had prepared. It was not controversial, but historical in its nature, and there was nothing to call forth the expression of any views conflicting in any way with those advanced by the author. It was now his pleasing duty to propose that the best thanks of the Institute be given to Don Pablo for his interesting contribution to its proceedings.

The vote of thanks was carried by acclamation.

Don PABLO DE ALZOLA thanked the President, the Council, and the members, in the most heartfelt manner, for the vote of thanks just passed, and also for having been selected to prepare a paper for the Institute. He had not dedicated his life to metallurgy, and he therefore felt that he was only on the threshold of a subject in which so many eminent scientific metallurgists had preceded him.

The PRESIDENT said the next paper was by Mr. William Gill, on the present position of the Iron Ore Industries of Biscay and Santander. It would be remembered that in 1882 the author had contributed an important paper on the same subject. In his present paper he had brought his information fully up to date, and his memoir was the most complete treatise on the subject ever written. The large number of maps and diagrams with which it was illustrated could not fail to add to its value, and would render it an authoritative guide to the mines to be visited.

The following paper was then read:—

THE PRESENT POSITION OF THE IRON ORE INDUSTRIES OF BISCAY AND SANTANDER.

By WILLIAM GILL, M.Inst.C.E. (Bilbao).

In view of the autumn visit of the members of the Institute to Bilbao, and its probable extension to the province of Santander, the author has been requested by the Council to prepare a paper descriptive of the mining districts to be visited, and of their present condition and future prospects. This he has much pleasure in doing; but in order that it may completely fulfil that purpose, some matters already described by him in 1882, and subsequently by various writers, must unavoidably be repeated.

BISCAY.

In the accompanying map (Plate V.) are indicated the principal iron ore deposits of this province. They follow for the most part the general stratification of the country, *i.e.*, from north-west to south-east.

The area within which these deposits occur measures about 24 kilometres (15 miles) in length, from the mine "San Prudencio," in the parish of San Miguel de Basauri (4 kilometres (2½ miles) to the south-east of the town of Bilbao), to the borders of the neighbouring province of Santander, where they are prolonged in the direction of Setares and Dicido. Its breadth, at right angles to the strike, may be taken at an average of 6 kilometres (3¾ miles).

The ore raised in this area is known in the market as "Bilbao ore," and, with the exception of the small group of mines at the north-west angle, is shipped at various places on the Bilbao River.

The groups into which this area may be conveniently divided, and their relative production in the years 1881 and 1895, are given in the following table, in order, from south-east to north-west:—

District.	1881.	1895.
	Metric Tons.	Metric Tons.
Above Bilbao, Ollargan, El Morro and Miravilla .	44,352	401,832
Below Bilbao, Abando and Iturrigorri	28,926	205,833
„ Alonsotegui and Gueñes	...	15,306
„ Castrejana (Primitiva). . . .	10,850	30,390
„ Matamoros	568,149	1,740,999
„ Triano, Somorrostro, and El Regato .	2,031,055	1,891,313
„ Galdames, Sopuerta, and Arcentales .	116,743	366,038
Totals . . .	2,800,075	4,651,711

From the foregoing table, it will be seen that in the fourteen years' interval the output over the whole district has nearly doubled, and that the relative importance of the various groups has changed.

The older Campanil mines have virtually become exhausted, and only a few are still at work; whilst new groups, untouched in 1881 (like Sopuerta), and others, then only incompletely and inefficiently opened out (like Ollargan, El Morro, and Miravilla), have since been systematically developed and are yielding good returns.

The bulk of the ore lies in the Triano and Matamoros districts, and then tails off at either end in branches and spurs; while the important districts of Galdames and Sopuerta lie by themselves to the south-west of the main ore-mass.

Before proceeding to describe the various groups of mines and their working, it may not be out of place to say a few words upon the formation of these mineral deposits, and of the relation of the various iron ores found therein to one another, and to the stratification in which they lie; though it is not possible, within the limits of this paper, to more than briefly refer to them; and all those who are interested in following up in detail the geology of Biscay may be referred to the exhaustive and excellent work of Don Ramon Adan de Yarza, the chief Government engineer of mines of the province, published in 1892 under the auspices of the Royal Commission for the Geological Survey of Spain. They will also find useful and interesting notes in several pamphlets and papers by other writers, enumerated in Appendix C.

The small map (Plate VI.), which is copied from that published

by the Royal Commission for the Geological Survey of Spain, shows the general geological features of Biscay and a portion of the neighbouring province of Santander.

The rocks that form the stratification of nearly the whole of the province are of the Cretaceous period (upper and lower), with frequent outcrops of volcanic rocks in the neighbourhood of Bilbao (trachyte) and of Guernica (ophite).

In the map above referred to, it will be seen that an extensive stretch of lower Cretaceous rocks traverses the centre of the province from north-west to south-east. These rocks present an anticlinal fold, whose axis follows approximately the line A B traced on the map. The strata to the south-west of the line dip to the south-west; those on the opposite side dip to the north-east. This general rule is departed from in places where faults occur.

The greater part of the ore-masses lie on the Cenomanian beds of micaceous sandstone; whilst they are often covered by calcareous shale, which again is above the compact limestone, so that in general the ore-mass occupies the place of the latter, with which it is often intimately connected. This is more particularly to be observed in the Campanil deposits, to which reference will be made hereafter.

The ore-masses occur mostly in the form of beds and pockets, and follow the configuration of the limestones and sandstones in which they lie. At places they appear like veins, from the effect of faults and dislocations in the strata; but the old idea (formed before these deposits were first worked on a large scale) of mountains of ore is fallacious, and has often led to erroneous calculations of quantities, involving waste of money in their development.

Four classes of ore are known locally in the district—

Vena	Red hæmatite	Soft, purple, compact, and often powdery.
Campanil	Red hæmatite	Compact and crystalline, and often accompanied by rhombohedrons of carbonate of lime.
Rubio	Brown hæmatite (limonite)	Hydrated ferric oxide, brown streak; its principal gangue siliceous.
Carbonato	Spathic ore, or siderite	Of two classes; (*a*) grey granular and siliceous; (*b*) creamy-white, laminated, and crystalline.

Vena is generally the purest of the Biscayan ores, and was

formerly the only one used, so long as the production was limited to supply the wants of the Catalan forges of the country.

Campanil was the first ore worked when the discovery of the Bessemer process gave a great impetus to the mining industry of the province. It is now nearly exhausted, but still commands a better price than other classes for special purposes. It is an epigenesis of the spathic ore, whose crystalline structure it retains; whilst in the Vena this has partially or totally disappeared.

Rubio frequently appears in cellular and concreted forms, much mixed with clay and siliceous matter, and is often associated with crystals of iron pyrites, rendering its careful selection necessary for Bessemer purposes. It is generally found uncovered (the reverse of the Campanil) and in contact with backs of clay, limestone, or sandstone. In former days, before the district was fully worked, the bold outcrops of Rubio formed a picturesque feature of the landscape.

The spathic ore appears sometimes in small quantities enveloped in lumps of Campanil or Rubio; at others, it forms pockets in the midst of the other ores, but generally it is found below them. In different parts of the district, large masses exist, notably in the Conchas, Inocencia, Juliana, and other mines; and it now finds a ready sale after calcination. A tabular analysis of these various classes of ore is given in Appendix A.

The mode of occurrence of these ores, and their relation to one another and to the limestone beds with which they are so intimately connected, points to their formation by hydrothermal action.

Springs charged with ferrous carbonate, dissolved by reason of an excess of carbonic acid, operated on the limestone beds; and, as the carbonate of lime is more soluble in water saturated with carbonic acid than the ferrous carbonate, it has been replaced by the latter, which in its turn has been transformed into red or brown hæmatite by a subsequent loss of carbonic acid and absorption of oxygen.

In many parts of the district, the hydrothermal action on rocks of other composition has been less, limiting itself to impregnating the sandstone, or to filling in the clefts and cavities formed by faults and dislocations.

In the Ollargan district, above Bilbao, a large quantity of small

gravelly ore, known as "chirta," lying superficially and mixed with clay, has been worked for a long time under the supposition that its origin was alluvial; but borings taken by Don Ramon Adan in 1890 led him to consider that this ore is not a gravel, but a concreted deposit, because these small stones embedded in clay are found at various depths, and even in the midst of, and underneath, the compact ore-masses in the neighbourhood. And to this effect he quotes the late Dr. Stapff, who is of opinion that the hydrothermal springs which gave rise to the compact ore have in such cases been highly diluted, and the slow decomposition of the rocks (which themselves are of impermeable argillaceous nature) has produced an argillaceous residuum, combined with oxide of iron, which later formed into concretions or nodules in the clay itself.

The mode of formation of this class of iron-ore deposit is of interest, as assisting to explain the occurrence of large deposits of a somewhat similar class that are now being worked in the Cabarga Mountain in the province of Santander, and which will be described later.

Lastly, in the district of Rigoitia, not far from Guernica, twenty miles to the south-east of Bilbao, veins of iron ore are found in the great mass of basic eruptive rocks that crop out all over that neighbourhood, at the junction of the Ophite and of the Cenomanian beds. As the former decomposes with great facility, and takes on a ferruginous appearance, a large portion of this district has been registered for iron-ore mining claims, while in reality the rocks have only a varnish of iron oxide. There are nevertheless, some small veins of brown ore there, and some day, when the Bilbao ores become scarce, they may be worked for local purposes; but as they contain a higher percentage of phosphorus with a lower percentage of metallic iron, and the quantity is not considerable, they can never replace Bilbao ores.

In Plate No. VII., figs. 1 to 6, some longitudinal and cross-sections are given at various places in the district; some of which are from borings taken by the Orconera Iron Ore Company, and others are, by permission, reproduced from Don Ramon Adan's work already referred to, and from other local surveys.

The Mines.

Working, Transport, and Shipping.

The map (Plate V.) indicates the more important mining concessions in the Bilbao district, and is, in part, a copy of that annexed to the author's paper in 1882, revised and brought up to date. Railways and other haulage systems, built subsequently, have been added; and those concessions where no sign of ore exists have been omitted, to avoid confusion in a map drawn to so small a scale.

Mining concessions in Spain are granted by the State, through the Civil Governor of the province in which the concession applied for may be situated; the conditions being, that there be free space and no prior claim. It is not necessary for the petitioner (who may be a Spanish subject or a foreigner) to prove the existence of ore.

The unit of measurement adopted in alloting these concessions is a rectangle of 100 metres square (*i.e.*, one hectare). This is called a *pertenencia*, and a mine may contain any number of such rectangles, not less than four.

Between the mines free spaces of irregular form frequently occur. When these contain less than four pertenencias, or are of such form that they cannot be subdivided into pertenencias, they are termed *demasias*, and are granted to the first of the concessionaires of the mines surrounding the space, who may petition for the same, or, should they renounce their claim, then to the first petitioner.

The concesssions, alike to mines and demasias, are granted in perpetuity, subject to an annual payment to the state of a surface-tax of four pesetas per pertenencia for iron ore. There is no obligation to work the mine, and the title, once granted definitively, cannot be cancelled, except through non-payment of the surface-tax.

Certain periods and conditions are stipulated for the demarcation of the concession by the Government engineers, for lodging protests, and for other formalities.

The laws governing Spanish mining are :—

(*a*) The law of 6th July 1859, as reformed on 4th March 1868.

(*b*) The regulations for application of same, dated 24th June 1868.

(*c*) The "Decreto bases," or basis for a new mining law, dated 29th December 1868.

The "Decreto bases" being conceived in a much more liberal spirit than the law of 4th March 1868, and being in many points in direct contradiction thereto, and the new law contemplated by the "Decreto bases" never having been compiled, it can easily be seen in what a confused tangle Spanish mining legislation has been for many years. There are also the interminable series of Royal Orders and judgments of the Council of State, often contradictory, attempting to clear up disputed or doubtful points.

In the case of the Bilbao district, there is the additional drawback that, when the laws of 1868 were framed, large open-cast workings were unknown, and their regulations, being adapted to underground working, are in many cases inapplicable. Year after year the new law, adapted to modern requirements, is promised, but is not forthcoming. Still, in justice to existing laws and regulations, it must be said that they are conceived in a liberal spirit, their object being to secure firmly the possession of the concession to the concessionaire, subject to a minimum of restrictions.

The mining concession gives no right to occupy or use the surface land, but empowers the concessionaire to expropriate it in the event of his not being able to come to terms amicably with the landowner.

The taxes paid to the Government and local authorities in respect of iron ore in this district are at present as follows:—

(*a*) Surface tax, 4 pesetas (2s. 8½d. at present exchange) per hectare.

(*b*) A tax of 2 per cent. on value of ore at quarry mouth, which amounts to from 8 to 10½ centimos per ton (0·65d. to 0·85d.).

(*c*) Port tax, 0·75 pesetas (6d.) per ton shipped, exclusive of a new tax on navigation now under discussion in the Córtes.*

The method of working the mines has undergone no change worthy of note since 1882. The quarries are worked open-cast, with one or two exceptions.

The more recently developed mines, and those of the larger companies and firms, are worked in a systematic and orderly manner in consecutive lifts, and the rubbish is led away to barren ground, often at some distance.

* Since this was written the tax on navigation has been fixed at 0·20 peseta per ton for iron ore exported from Atlantic ports, and at 0·10 peseta for that from the Mediterranean and from Seville.

But the older and smaller mines, surrounded on all sides by neighbours, have continued to suffer from want of spoil ground, and have had to work over their rubbish heaps, in many cases several times.

The accompanying photographs show various workings. They are:—

Campanil (Older) Mines.

Plate VIII.—Mine Indiana. Messrs. Ybarra, Chavarri & Arana.

Plate IX.—Mines San José and Demasia San Antonio. Sr. Don José M. Martinez de las Rivas; La Compañia Explotadora.

Rubio and Vena Mines.

Plate X.—Mine Concha 1. Orconera Iron Ore Co., Limited.

Plate XI.—Mines Concha 3 and 7. Société France-Belge.

Plates XII., XIII., and XIII*a*.—Mine Orconera. Orconera Iron Ore Co. Limited.

Plate XIV.—Mine Amistosa. Somorrostro Iron Ore Co., Limited.

Plate XV.—Mine Parcocha. Parcocha Iron Ore Co., Limited.

The general practice in the district is to let the raising and loading (and often the intermediate haulage) to a contractor, at a rate per ton of clean ore delivered to the stock heaps alongside the various railways.

The cost of raising and loading the ore has not varied much since 1882; if anything the labour is slightly less, when reckoned in English money, owing to the increase in rate of exchange; on the other hand, all material ordered from abroad costs more.

A table of the wages paid for various classes of labour is given below:—

	Pesetas.
Foremen	5·25
Men occupied in charging and firing shots	3·75
Drillers	3·50
Labourers	2·75 to 3·00
Labourers at calcining kilns	3·00 to 3·35
Boys	2·00
Horse-drivers	3·00
Masons and bricklayers	4·25
Engine-drivers	3·50 to 6·00
Firemen	2·75 to 3·00
Brakesmen	2·90 to 3·10
Train guards	3·55 to 4·00
Blacksmiths	3·50 to 6·60
Strikers	3·00 to 3·25
Fitters	3·75 to 6·00
Carpenters	3·75 to 5·25

The prices paid to contractors for raising and loading the iron ore vary from six to eight reals per ton (1s. to 1s. 4½d. at present exchange). This price includes the removal of the rubbish cleaned from the ore, but not the surface baring, which differs much in quantity in the various mines. For instance, in Orconera No. 5 (of the Orconera Iron Ore Company), of which a section is given (Plate VII. Fig. 2), there are nearly one million cubic metres of clay, sandy rock, and shale, to be removed to uncover the bed of ore beneath.

A portion of this has been removed by steam navvies, the only case of the employment of excavating machinery in this district. The average cost per cubic metre was ptas. 1·143 (9¼d.), including digging, filling, transport, and tipping, with all repairs to plant, and laying and maintenance of temporary roads. This was little less than by hand, owing to the hard nature of much of the stuff; but the saving in time and in the number of men employed was advantageous, as the working site was difficult of access, and with poor accommodation for lodging a large number of men.

In the open-cast work the rock-boring continues to be done by hand, although at intervals attempts have been made to introduce machinery for the purpose.

Jumpers are used exclusively, even for small holes bored to split up the masses of ore brought down by the larger blasts.

The holes are usually known as "one-handed," or "three-handed," according to the number of men employed; "two-handed" holes are very rarely bored.

Three-handed holes vary from 1·50 (4 feet 10 inches) to 8 metres (26 feet 3 inches) in depth, and are bored by three men: the number sometimes increasing after 5 metres (16 feet 3 inches) at the rate of one man for every 1½ metre additional.

They are started with a chisel-pointed jumper 2½ metres (8 feet 3 inches) long by 38 millimetres (1½ inch) diameter of shank, and 44 millimetres (1¾ inch) of cutting edge at the bit, following on with others of increasing length and diminishing diameter, according to the depth of hole.

The time occupied in drilling one metre in various classes of ore and rock is, approximately, as under:—

	Hours.
In Vena	¾ to 1
,, Campanil	1 ,, 1½
,, Stiff Rubio	2 ,, 3
,, Carbonate (hard)	4 ,, 5
,, ,, (softer)	2 ,, 3
,, Limestone	2 ,, 3
,, Schist	2 ,, 3
,, Hard black schist	4

The holes, when bored, are prepared for the working charge in the following manner:—

Firstly, successive and gradually increasing charges (called "secadores") of No. 3 dynamite are introduced, and fired, in order to form a chamber in the bottom of the hole to receive the working charge.

These "secadores" vary in number and amount of explosive employed, according to the depth of hole and the class of ore or rock, somewhat in the following proportion:—

Number of Successive Charges.	Amount of Explosive in each for		
	Vena.	Rubio.	Carbonate.
	Grammes.	Grammes.	Grammes.
1.	336	420	420
2.	1008	1680	672
3.	2520	5040	1008
4.	...	10920	1680
5.	...	...	3360
6.	...	...	4620
7.	...	...	6720
8.	...	...	8400
9.	...	...	10080
	Kilos.	Kilos.	Kilos.
The respective working charges would be approximately	25	75	37·5

The hole being chambered, the working charge is put down and tamped with a wooden stemmer, and the fuse left ready for igniting.

The quantity of ore brought down by the larger shots of 16 and 18 feet varies naturally with the class of ore, and the more or less favourable situation of the holes and of the face.

The maximum effect is obtained when the face and two sides project, and a foot shot and a back shot can be fired in quick succession. In this way 6000 tons was brought down at Orconera No. 1, in 1893, with two 16-feet holes.

The Table B in the Appendix gives particulars of eleven 9 to 20 feet holes, recently fired in various classes of ore, both as to time, cost, and effect; the latter is rather below the average.

One-Handed Holes.—These are employed to split up the rocks brought down by the larger blasts above described. In boring them a chisel-pointed jumper is used, 2 metres (6·8 inches) long by 25 millimetres (1 inch) diameter in the shank, and with a cutting edge of 30 millimetres ($1\frac{1}{8}$ inch).

In these holes the time occupied in boring average rock and ore is:—

One foot in depth	$\frac{1}{4}$ to $\frac{1}{2}$ hour.
One metre in depth	2 hours.

The firing takes place at prescribed hours—from 8 to 8.30 A.M., 12 noon to 1 P.M., and 4 to 4.30 P.M.—and is preceded by the following signals given by a bugler placed in a position to see all the shots:—

One note, when the hole is ready for the charge;

Two short notes, when the hole is charged;

Three short notes, when the fuse is about to be lighted.

The termination of the firing is announced by one long note. The additional precaution is taken of showing red flags, to warn passers-by from approaching the quarries during the firing hours. All shots are fired by ordinary fuse, ignited by hand.

The favourite explosive is dynamite of No. 3 quality, sold as of 33 per cent. nitroglycerine. Other high explosives and so-called safety explosives have been frequently introduced and tried; but, though superior in effect to the dynamite in hard compact stone, such as Campanil or spathic ore, they do not produce their maximum energy in the Rubio, which is of a softer, spongier nature, and full of cavities and loose "backs."

In breaking down the ore after blasting, and in classifying it, the hammer, spade, hoe, rake, and basket are employed. The waste of baskets is enormous; but, seeing the necessity of selecting the ore and separating it from the rubbish in the act of loading, the rake and basket seem to suit the purpose fairly well.

The small stuff left behind by the rake is, when it contains sufficient ore to warrant the extra expense, spread out on the floor of the quarry to dry, and then passed through a screen.

The total number of persons employed in the mining district during 1895 was respectively:—

Men	8734
Women	62
Boys	209
Total	9005

The output over the whole district was approximately 4,650,000 tons; thus giving 516⅛ tons as the annual output of each person employed, but evidently this is below the real average per man actually working in the mines.

The hours worked are:—In January, February, November, December, from 6.30 A.M. to 5.30 P.M., with rests of two hours; in March, April, September, October, from 6 A.M. to 6 P.M., with rests of two hours; in May, June, July, and August, from 6 A.M. to 7 P.M., or 5 A.M. to 6 P.M., with rests of two hours. But these are modified by the almost universal custom of task-work prevailing in the district; so many waggons of ore and rubbish are allotted to each gang as the day's work, and on completion of these, the men can go home. Hence it sometimes happens that the task in the quarries is finished by four o'clock in the afternoon. In that case a supplemental task is often given and paid for as overtime.

Feast days are numerous, and what with these and bad weather, the number of effective working days in the year may be taken at 285.

Accidents in the district are not so frequent as might be supposed, and are principally caused by waggons running over the men or by falls of rock; more rarely by explosion, which is remarkable, seeing the careless way in which the dynamite and caps are handled.

An improved set of mining regulations has been in preparation for the past two years, but has not yet appeared; it is sadly needed.

With regard to the sanitary condition of the mining district, some improvement has been effected in the years that have elapsed since 1882; and although, judged by modern standards, the lodging, clothing, nutrition, and hygienic surroundings of the workmen fall far short of what they should be; yet, compared

with other provinces of Spain, their lot is enviable. Consequently, a constant influx of outside labour, attracted by the high wages paid, sets in permanently towards Biscay; and, the supply far exceeding the work available (except for two months in harvest time), there is always a large floating population wandering about in search of work. This in the winter time is the cause of much distress.

The fluctuating character of the bulk of the mining population renders it difficult to place the district permanently on a sound sanitary basis; nevertheless, the very complete and efficient organisation established in 1881, and known as the "Triano Hospitals Society," exercises, although a purely voluntary association, a beneficent influence, not only in the cure of sickness and the treatment of the numerous cases of accident, but also in watching against the spread of zymotic disease; so that small-pox and typhoid fever, in an epidemic form, may be said to have disappeared. This association is supported jointly by the employers and their workmen; the former pay a tonnage rate upon all iron ore raised, loaded, transported, or shipped (as the case may be), and in return deduct 2 per cent. from the men, which partially recoups them for their contribution.

In return for his 2 per cent. the workman is entitled to:—

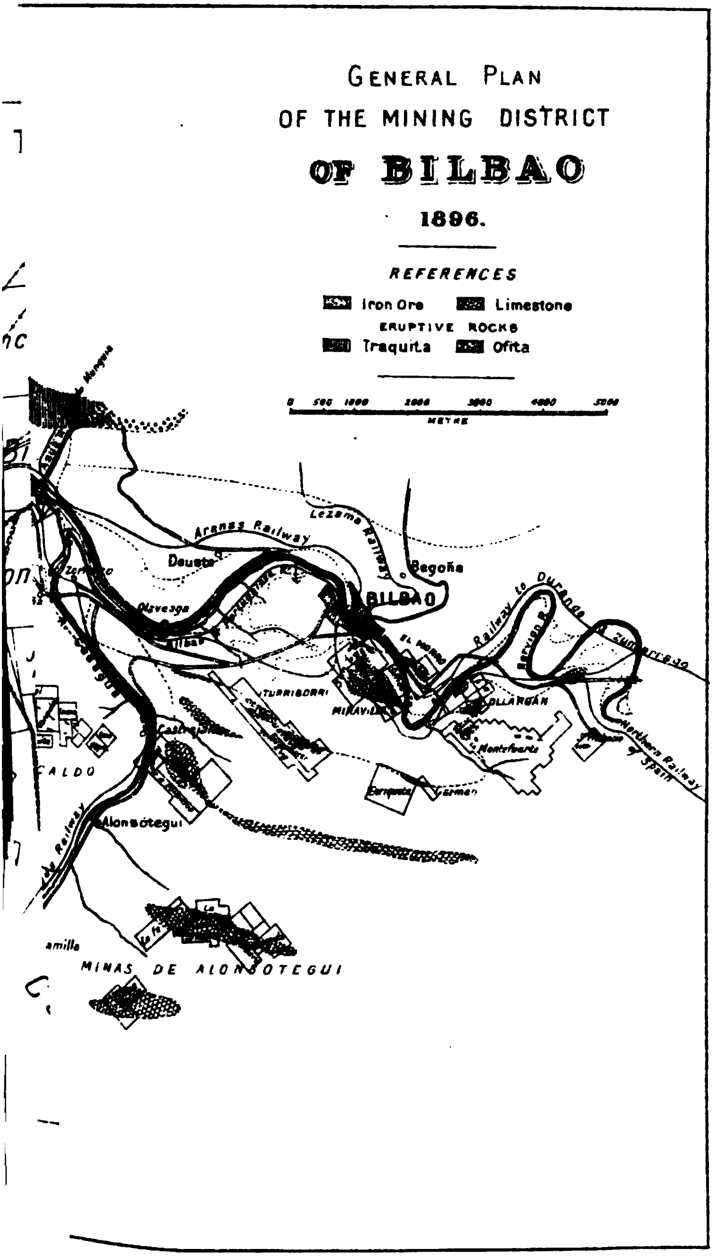
(*a*) Medical and surgical attendance, with medicines and food, as an in-patient at either of the three hospitals, in case of sickness or injury.

(*b*) Medical advice, attendance, and medicines for himself and family, at his own home, in case of sickness.

(*c*) Some compensation to the workman himself for loss of sight or limb, and to his widow, in case of his death from injury. (This, however, is small, owing to scarcity of funds.)

The main hospital at Gallarta, and the branches at Matamoros and Galdames, are fitted up with all modern requirements. During 1895 the number of in-patients was 1639, of whom ninety-three died, being 5·67 per cent. The number of operations was seventy-eight, while the deaths of patients operated on were only two.

Of course, in addition to the fluctuating population above referred to, there is a large and increasing number of permanent residents; men who have received fixed employment, and who



Ballantyne, Hanson & Cº Edinburgh & London.

PLATE VI.

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE VII.

FIG. 7.

COBARON.

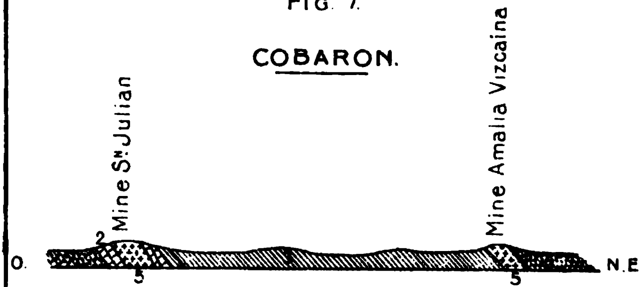


FIG. 8.

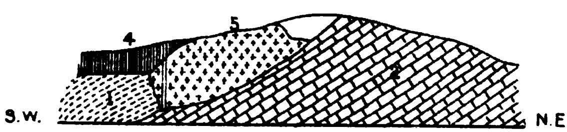
COBARON.

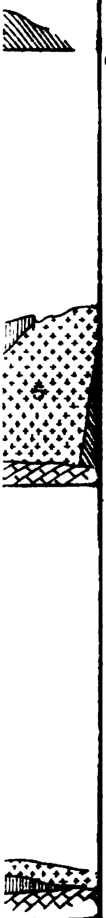
Mine Onton ó Sn. Julian

FIG. 9.

SETARES.

Mine Ceferina





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E OF SANTANDER

eadas. Etc. (Obregon Group)

Fig. 10.

gitudinal Section.

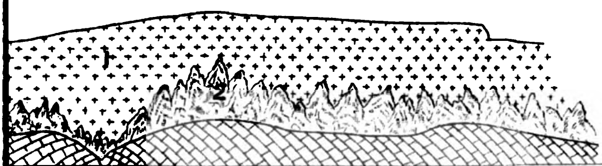


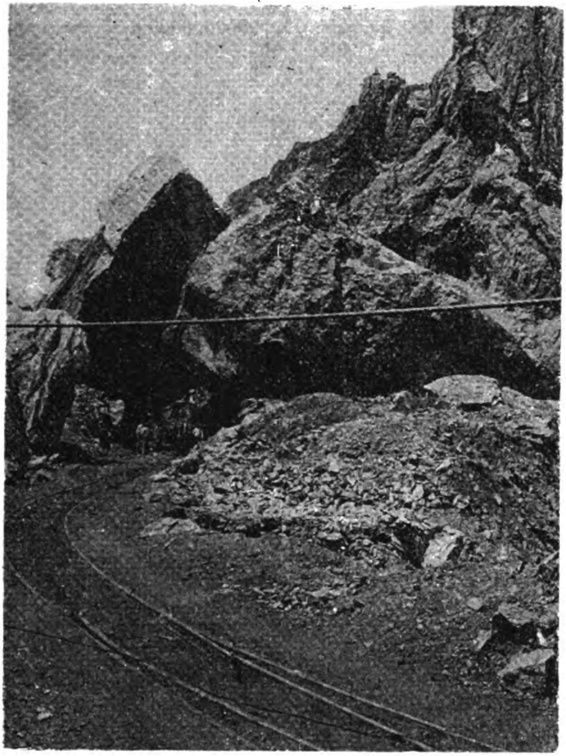
Fig. 11.

Cross Section.

2 3 4

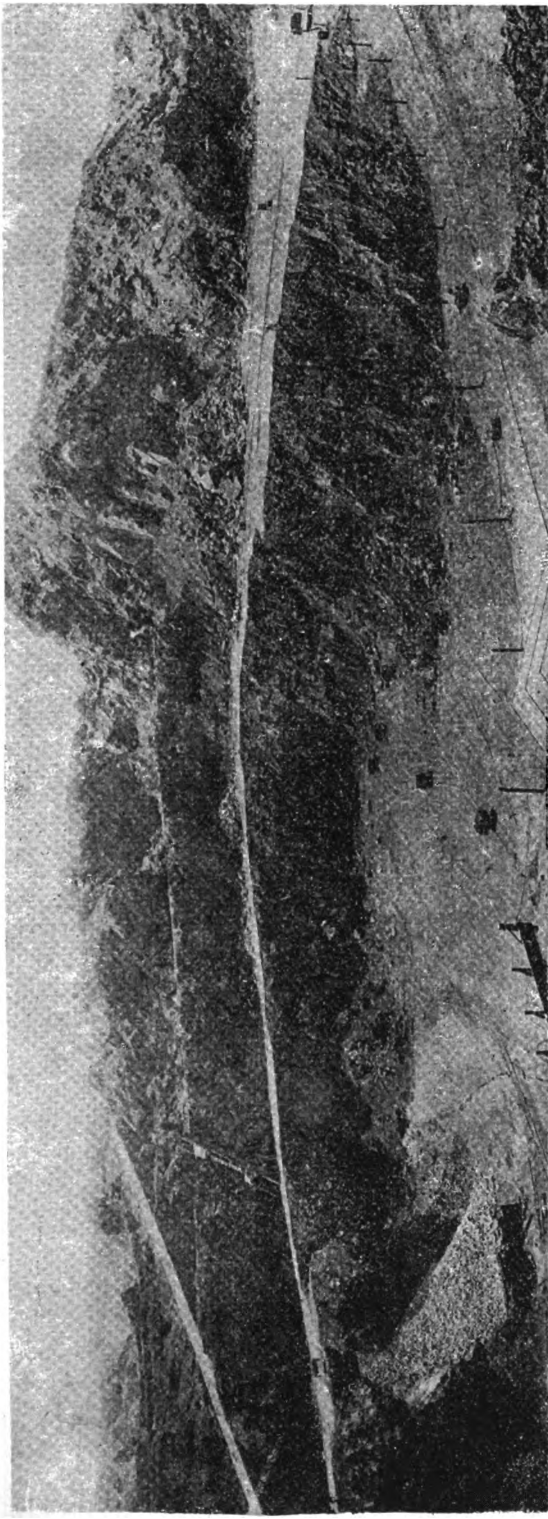
omias. Compact Limestone. Clay.

PLATE VIII.

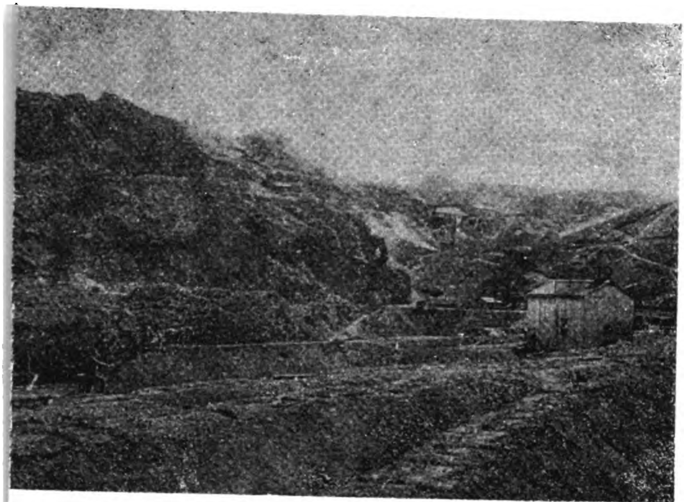


Mines of Triano and Somorrostro.

PLATE IX.

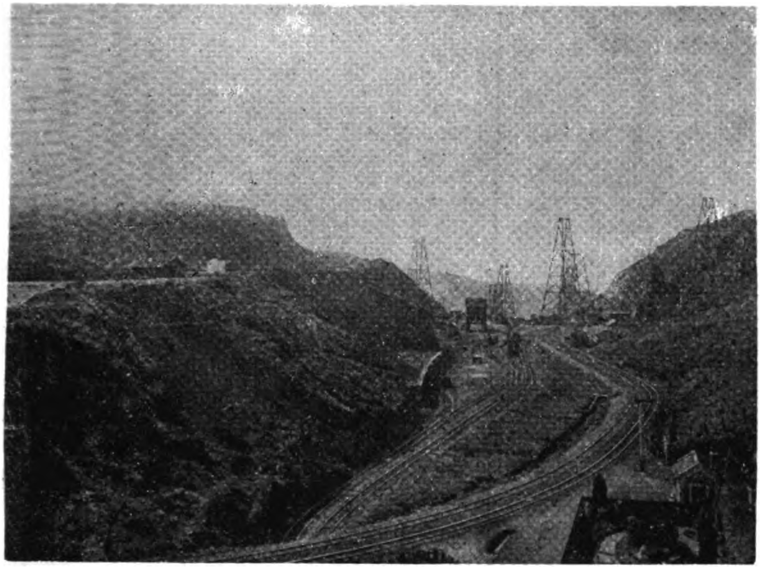


Mine Concha I.



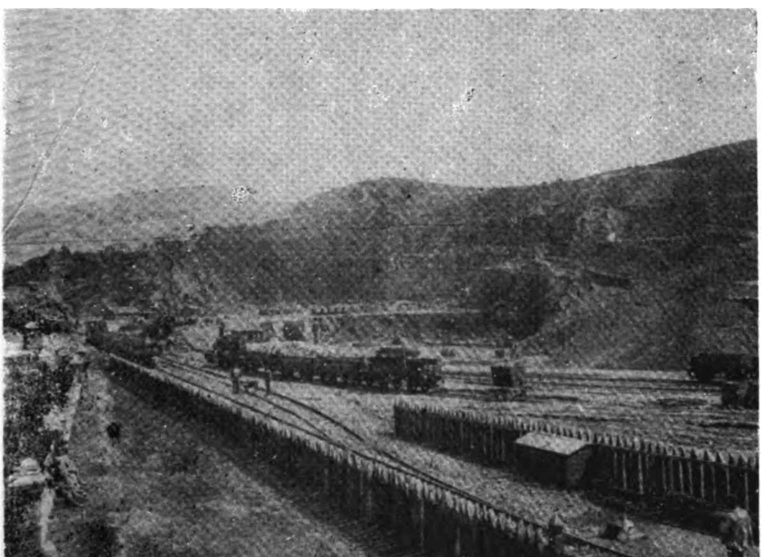
VII.

PLATE XIII.



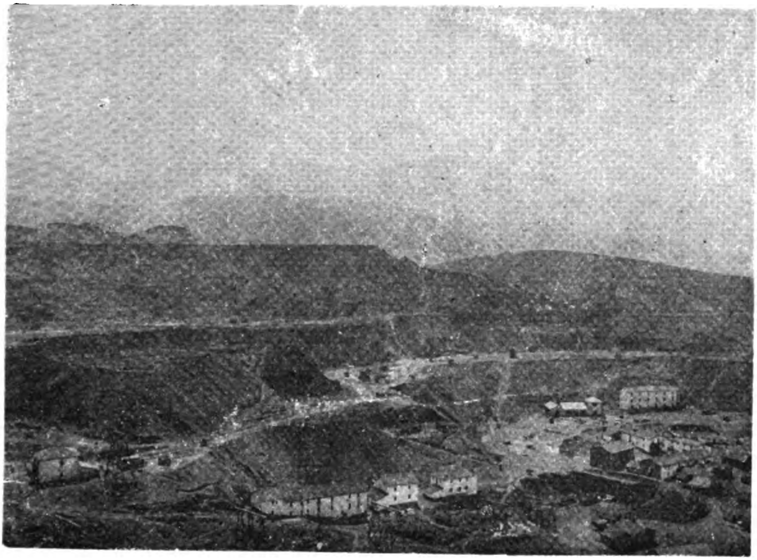
Orconera Mine.

PLATE XIIIA.



Mines Orconera III and IV.

PLATE XIV.

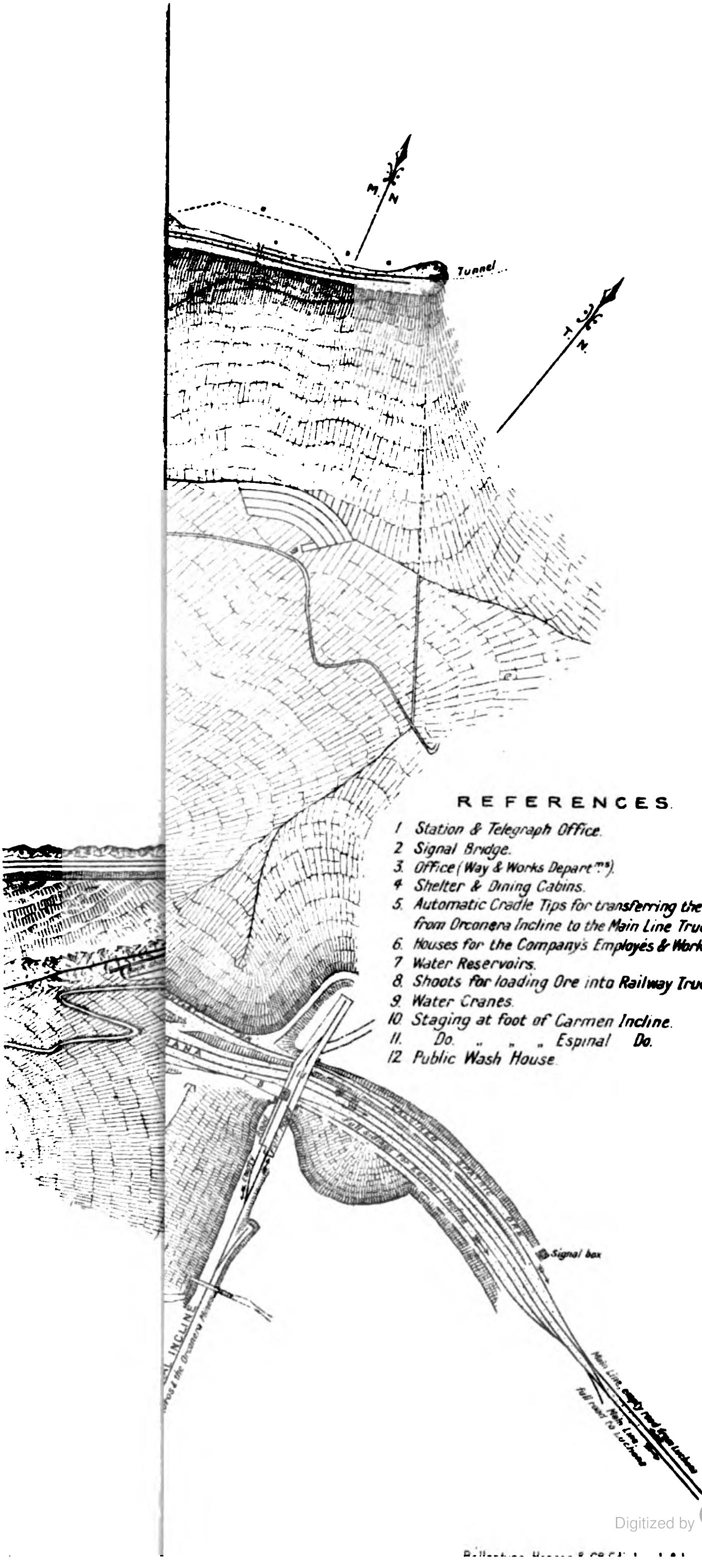


Mine Amistosa.

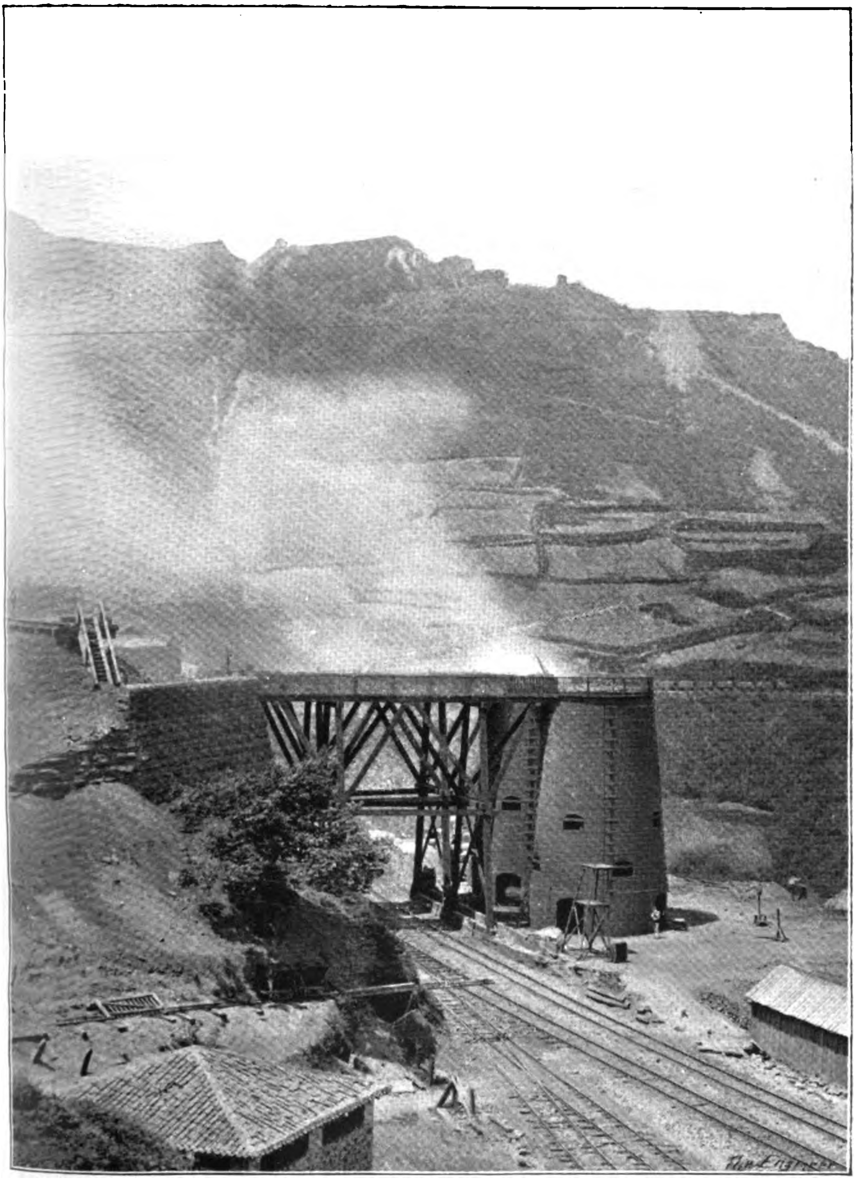
PLATE XV.

Parcocha Mine.

PLATE XVI.



M. N
T. N
Tunnel
REFERENCES.
1 Station & Telegraph Office.
2 Signal Bridge.
3 Office (Way & Works Depart.ts)
4 Shelter & Dining Cabins.
5 Automatic Cradle Tips for transferring the Ore from Orconera Incline to the Main Line Trucks.
6 Houses for the Company's Employés & Workmen.
7 Water Reservoirs.
8 Shoots for loading Ore into Railway Trucks.
9 Water Cranes.
10 Staging at foot of Carmen Incline.
11. Do. " " " Espinal Do.
12 Public Wash House.
Signal box



Calcining Plant for Spathic Ore. Orconera Company.

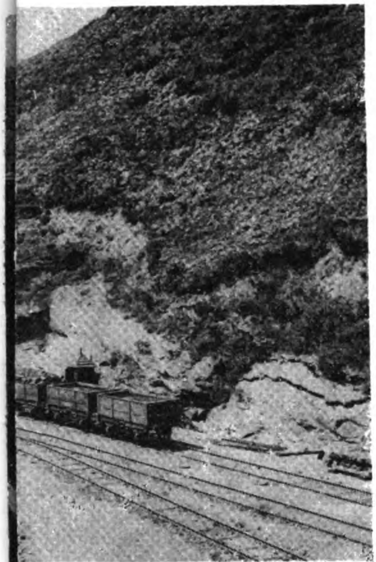
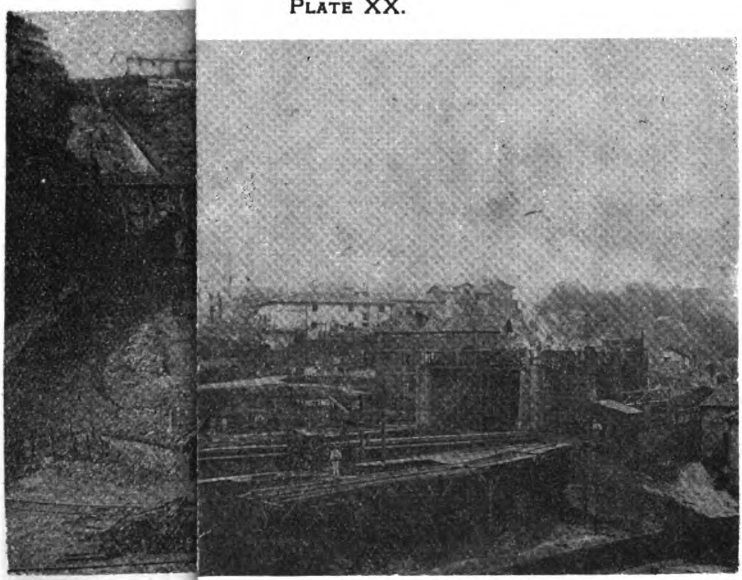


PLATE XX.



Franal Station of Endless Chain Railway.

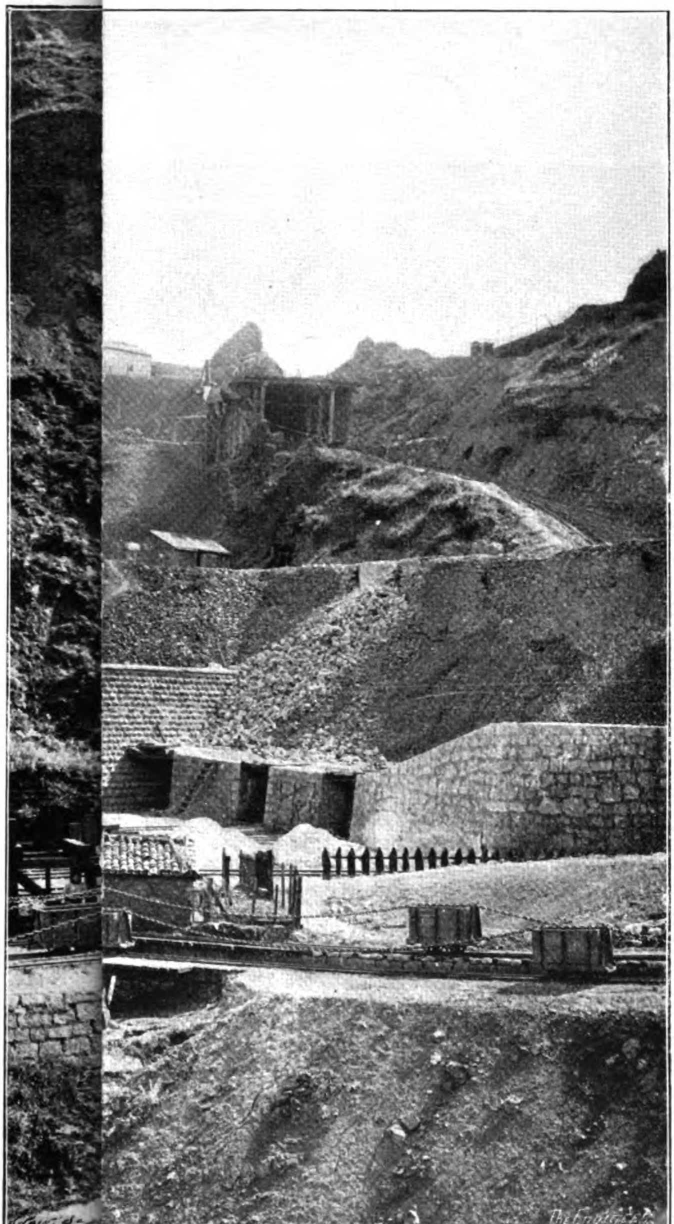


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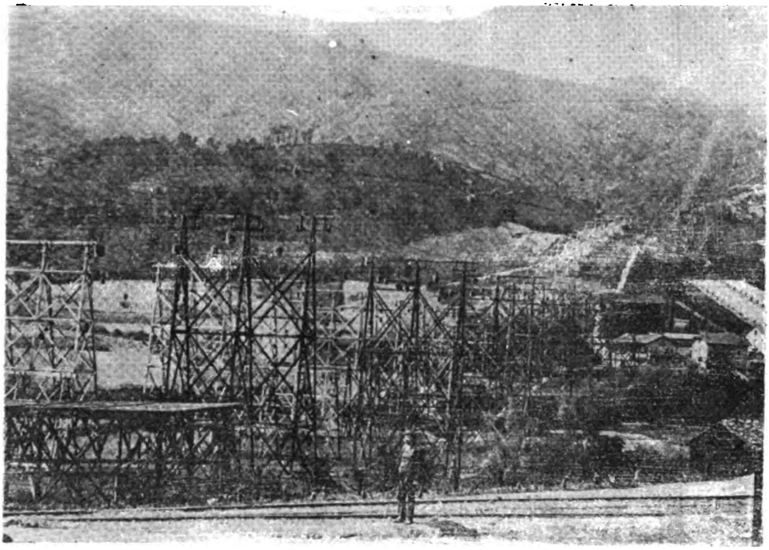
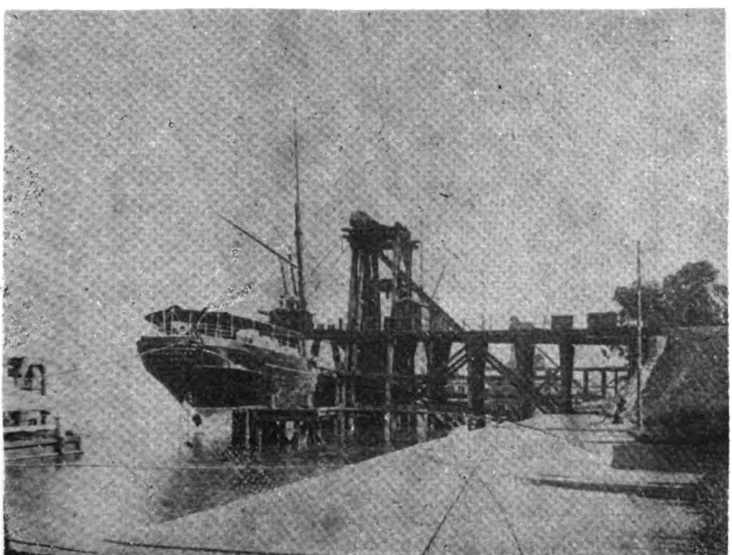
PLATE XXIV.



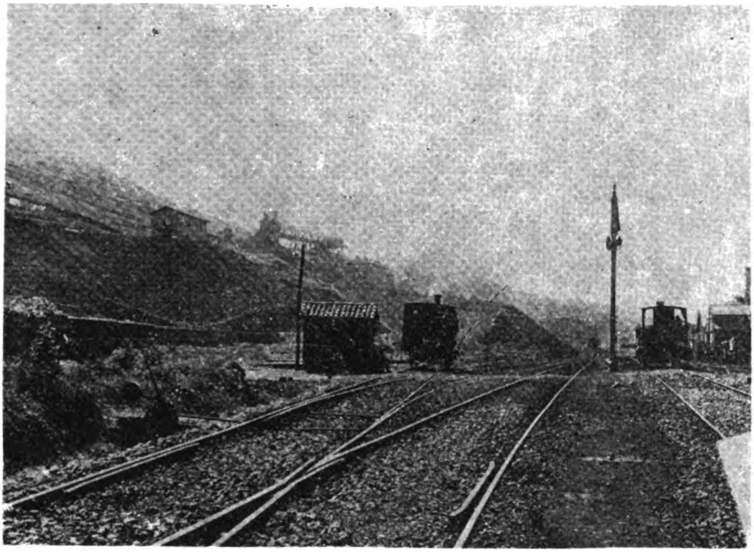
Luchana Shipping Staithes.

PLATE XXV.



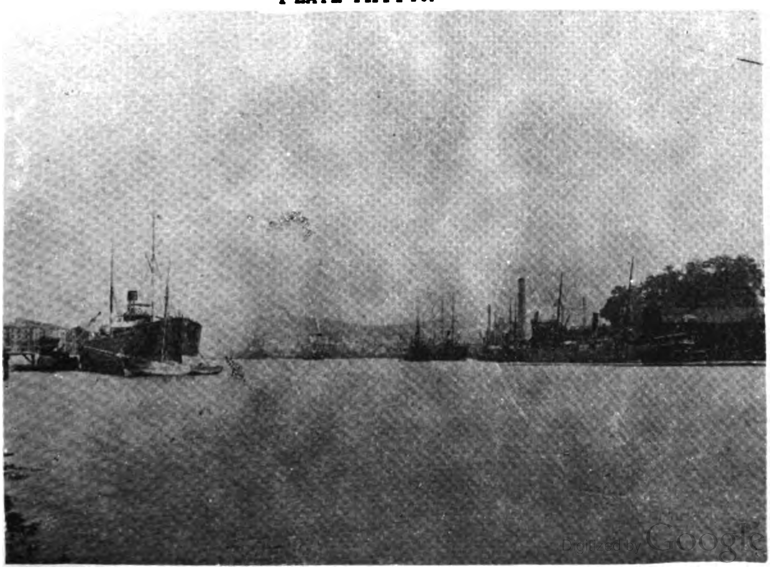
Orconera Company. No. III Shipping Staith.

Plate XXVI.



Ortuella Terminus.

Plate XXVII.



marry and settle down in the district. For the families of these, elementary education is provided on an ample scale by the local authorities; although, in a district where the wages paid to boys exceed those earned by adults in other provinces, it is difficult to ensure an adequate attendance at school.

Female labour, so prevalent in 1881, has almost disappeared.

Labour troubles, though rare, are not unknown in the district, thanks chiefly to Socialist agitators, who seek to sow discord between employers and employed, and who thus alienate the sympathies of those who would gladly co-operate in efforts to improve the position and comfort of the workmen.

For the protection of the interests of the mining industry of this district, an association was formed in 1887, called the "Circulo Minero," to deal with questions affecting the general mining interest, such as imposition of taxes, Government regulations, labour difficulties, and the like, and has rendered good service in these respects.

Concentration and Calcination.

Attention has for some years past been turned to the utilisation of the carbonate of iron (spathic ore). Attempts to dispose of it, in a raw state, proved unsatisfactory; but, after experiments in calcination had been made, it was gradually recognised that a good marketable ore, richer in metallic iron (though higher in sulphur) than the Rubio, could be produced; so plant for calcining has been put down at several mines, and the roasted carbonate meets with a ready sale.

The first kiln erected in the district was a small one of masonry built at Cobaron in 1882 by Mr. Joseph MacLennan, but the first to take up the business of calcination on a commercial basis was the Luchana Mining Company, in 1891, at Regato, for the mine "Juliana," where a considerable bed of spathic ore exists.

This Company's kiln, built after the Cleveland pattern, is of iron shell with fire-brick lining; its dimensions are 38 feet in height, and 20 feet internal diameter, with three openings for drawing the calcined ore. The daily output, until it stopped in 1893, was 130 to 150 tons (in 24 hours); and the consumption of coal about 2 tons per 100 tons of output. Calcination has

recently been resumed in this kiln. The Société Franco-Belge des Mines de Somorrostro, in 1891, commenced a protracted series of experiments at Mine Concha No. 3, with a trial kiln about 30 feet high by 13 feet internal diameter. A description of this kiln, and of the results obtained, was given in 1895 to the French Society of Civil Engineers by Professor Jordan (under whose general direction the experiments were conducted).

Acting on the experience thus gained, the Société Franco-Belge put down, in 1895, at its railway station in Ortuella, a permanent calcining plant consisting of 2 kilns, each giving a daily (24 hours) output of 75 tons.

The initiative of the Luchana Mining and Franco-Belgian Companies was soon followed by others, and there are at the present time 15 kilns at work in the district, with a total daily output of 1150 tons. The complete list is as under:—

Name.	No. of Kilns.	Daily Output Capacity (per 24 hours).	When Started.
Luchana Mining Company	1	130	1891
Franco-Belgian Company	3	210	1 in 1892 2 in 1895
Successors J. B. Rochet	2	150	1893
Orconera Iron Ore Company	2	156	1894
	1	...	in construction.*
Messrs. Allende & Seebold	1	80	1893
Messrs. Chavarri & Arana	3	200	1893 1894 1895
Somorrostro Iron Ore Company	1	75	1896
Don Cosme Echevarrieta	1	80	1893
	1	85	in construction.
Don Fernando Alonso	1	70	1896

Plate No. XVI. shows a plan and section of the calcining plant of the Orconera Iron Ore Company in Orconera Station, the site selected being the most central and convenient for bringing down the crude ore from the various mines to the kilns, and for despatching the trains of roasted ore to the shipping place at Luchana.

The crude ore is delivered on a gantry, and put to stock at a higher level than the top of the kilns; to which it is distributed from time to time, as required, in small tip-waggons.

The ore, after calcination, is wheeled out to a stocking-

* Since this paper was written, the Kiln No. 3 of the Orconera Company has been completed and put into work—its daily output being 120 tons of calcined ore—the increase being due to better arrangement of air flues than in Nos. 1 and 2.

platform at the foot of the kilns, arranged so that the train of empty railway-trucks can stand underneath it, and be filled in a short time through trap-doors in the floor of the deposit. The cross section on Plate XVI. shows this.

The trains of empty trucks are brought under this stocking-place by gravitation (on a falling gradient), and, when loaded, pass to a siding close to the main line, where they are marshalled in readiness to be hauled to Luchana.

The kilns are three in number, of which one is in construction. They are of brick, with fire-brick lining, and are hooped with steel bands at every two feet. They are 41 feet high by 13 feet internal diameter, with four doors for drawing the calcined ore; and the output of each of the two at work, per twenty-four hours, averages 78 tons.*

The men work in two shifts; from six to six, with the usual intervals for meals; and the number of hands employed at the two kilns now in work is sixteen; viz., eight at top and eight at bottom; exclusive of the gang for loading the calcined ore into railway trucks.

The crude ore is brought to the stocking-place at the top of the kilns in 7-ton mineral trucks, or 4½-ton incline trucks, according as it proceeds from the Matamoros or other districts. The shunting-engine on general service in Orconera Station does this work also.

Plate XVII. gives a general photographic view of the kilns and sidings.

The consumption of coal is insignificant, and ranges at present from 0·5 per cent. to 0·8 per cent. (by weight) of calcined ore; equal to about ¾d. to 1¼d. per ton. It varies, however, from one of the following causes:—

(*a*) Force and direction of wind; a strong south wind lowering the fire, and reducing the output of a kiln from 78 tons to 56 tons in a day.

(*b*) The proportion of fine stuff charged into the kiln.

(*c*) The proportion in which the crude spathic ores from various mines are mixed in the kiln, some ores being more porous and easily roasted than others.

(*d*) The quality of coal used (generally small stuff is bought from local merchants; and even ashes, coke breeze, &c., are used).

* See note on preceding page.

(*e*) The amount of air given.

The institution, therefore, of an accurate comparison of consumption between the various kilns in the district is apt to be difficult. Nevertheless it may be said that, *cæteris paribus*, the ore is better and more evenly calcined in a kiln of moderate diameter, say not exceeding 13 to 15 feet, and of 35 feet in height and upwards.

And this appears to be the general belief in the district, as, with the exception of the Luchana Mining Company's kiln before referred to, all the others are of about these dimensions.

The kiln of the Somorrostro Iron Ore Company at Arcocha contains some special features for regulating the distribution of air to the centre or the sides by means of flues that can be opened or shut at will.

The quantity of Calcined Ore exported in 1895 from the Bilbao river was 132,467 tons, in addition to which 15,045 tons were used in the Altos Hornos Iron and Steel Works.

Washing.

The success attending upon the concentration of iron ore by washing, in the province of Santander, has led to its introduction into this district, at present in a tentative manner and on a small scale. The few installations at present at work are on the "Patouillet" trough system, and turn out, each, about 100 tons of washed ore per day; the largest of these is that of Messrs. Larrucea & Lopez, at the Marta Mine.

The want of water in sufficient quantity at the mines, and the difficulty created by turning the mud from the washers into streams or into the Bilbao River, have hitherto prevented the introduction of washing operations on a large scale; but, undoubtedly as time goes on, the importance of saving all the ore possible will become more manifest, and a solution will be found for this problem here, as it has been in Santander.

TRANSPORT.

One of the most interesting features of the Bilbao district is, undoubtedly, the variety of haulage systems employed for the conveyance of the ore to the railways and the port, and the in-

genuity with which they are devised. Consequently, these appliances have been frequently described, and the author does not propose here to do more than call attention to those that are likely to prove of greatest interest to members during their visit to the mines; referring them for fuller description to his former paper, and to others subsequently written, of which a list is given in Table C.

A.—*Subsidiary Haulage from the Mines to the Railway Depôts.*

In the interval since 1881, the haulage by bullock carts, which at that time transported 24 per cent. of the total quantity raised, has gradually died out; and thus one of the most picturesque and primitive sights offered to visitors has passed away.

To the methods of mechanical haulage, already established in 1881, has been added that of the endless chain, adopted by the Société Franco-Belge in 1883 to connect certain of its mines with its railway terminus at Ortuella.

The various systems now at work are therefore:—

(*a*) Railways.
(*b*) Inclined Planes.
(*c*) The Endless Chain.
(*d*) Wire Ropeways.

Of these the principal examples are:—

1. The Matamoros Branch Railways of the Orconera Iron Ore Company, Limited.
2. The Orconera Incline of the Orconera Iron Ore Company, Limited.
3. The Endless Chain of the Société Franco-Belge des Mines de Somorrostro.
4. The Wire Ropeways (Hodgson type) of the Somorrostro Iron Ore Company, Limited.
5. The Wire Ropeways (Otto Bleichert type) of the Provincial Deputation of Biscay.

All these are either automatic or worked by steam-power, electric traction not having yet been applied in the district.

1. *The Matamoros Branch Railways of the Orconera Iron Ore Company.*—The Orconera Mines were originally worked in three levels, connected by horse-railways of 0·80 meter gauge, with surface shoots, and a tunnel shaft which delivered the ore into 4-ton waggons of the Orconera incline, standing on sidings in proximity to the brows.

But, towards the year 1886, the quarry faces had acquired such extension, and their distance from shoots and shafts was so great, that it was decided to change the system of working, and extend the meter-gauge railway from the inclined plane into all the quarries then opened out; conveying the ore direct from the faces, in trains of 4-ton waggons hauled by locomotives.

The alterations were completed in 1887, and the branch railways have since been extended from time to time, until there are 12 kilometres at present in work. Plates XII., XIII., and XIIIA. show them at various points of interest.

The main line is double, and runs up the valley that forms, roughly speaking, the centre of the Orconera Company's property, to a back shunt or V station, whence the branches to the various levels strike off at suitable gradients, in fan-like form. The ruling gradient is 1 in 30; but there are short lengths of 1 in 25, all falling in the direction of the mineral load.

Certain mines at the upper end of the valley, opened out since 1887, that lie at a considerably higher level than the branch railway, are connected with it by inclined planes. There are in daily service on these branches:—

4 Locomotives of 24 tons.
3 do. 14 ,,
2 do. 13 ,,
284 Mineral trucks, containing 4 to 4½ tons.
175 Iron and steel rubbish waggons, containing 2½ cubic metres each.

The mineral trains are formed by sixteen waggons (about 70 tons net load of ore).

The rubbish trains vary, according to the level of the rubbish tip to which they may be directed, from twelve to twenty-four waggons, as some of them have to be hauled up-hill.

A daily service for goods, coal, and materials between Luchana and Matamoros (*viâ* the Onconera railways and incline) is in operation, and affords convenience to the neighbouring Mining Com-

panies, and to the four mining villages in the mountain, which would otherwise have great difficulty in bringing up supplies, as they are situated from 1200 to 1500 feet above sea level, and there is no cart road.

The accompanying photographs, Plates XII., XIII., and XIIIA., will afford a better idea than verbal description of the character and extent of these mountain railways, which deal daily with about 2850 tons of ore, and 2000 tons of rubbish, besides merchandise, coal, and construction materials.

2. *The Orconera Incline.*—This incline was opened in 1880, for the purpose of bringing down ore from the extensive group of mines worked by the Orconera Company in Matamoros to a point on its railway (known as the Orconera Station) about 5½ miles from the shipping place at Luchana.

Its operation has since been extended to the Parcocha, Mendivil, and other mines in the same district.

The length of the incline is 1200 yards, of which 340 are upon a reverse curve.

The average gradient is 1 in 5·88, the maximum being 1 in 4·75; and the total fall from brows to foot is 612 feet.

The drums (two) are 15 feet in diameter, and 3 feet 3 inches wide on the rope tread. They are fixed overhead on ashlar piers, and are controlled by friction-brakes operated by a hand-winch placed at the brows.

The brake surfaces are cast iron upon cast iron. The top and bottom straps are lined with cast iron curbs acting upon four brake circles, 17 feet 6 inches diameter, on the drums.

The cables are of best plough steel, 4½ inches in circumference, and weighing 22 lbs. per fathom, tested to about 75 tons per square inch. Since the year 1892 they have been manufactured on "Lang's" patent lay.

The average life of a pair of cables since 1880 has been 2½ years; or 1,455,161 tons of ore brought down per pair of cables. Those recently taken off had been running as follows:—

Right hand, 2 years 11 months	947,037 tons.
Left hand, 3 years 8 months	1,233,317 ,,

The cables, when taken off, have still good work left in them, and are used on other inclines.

The shackle for attaching the cable to the incline waggons is of steel, weldless, with no bands, hoops, or external projections, so that it can take the curve pulleys easily. A chamber is hollowed out opposite each rivet-hole in the shackle to receive the strands of the rope displaced by the rivet. After riveting, the shackle is warmed, and then an alloy of six parts lead and one part antimony is poured in, filling all the interstices in and about the rope. This alloy is hard, and does not contract on cooling, and the rope has never shown signs of movement in the shackles. From time to time the shackles are carefully annealed.

The roads are double from the brows to within a short distance of the foot. At the junction a pair of self-acting points regulate them for successive up and down trips.

The gauge is one metre, and the rails are of steel (Vignoles section), 56 lbs. per yard, spiked to oak sleepers, $4\frac{1}{2}$ inches × $8\frac{1}{2}$ inches, spaced 2 feet 6 inches apart.

The full road passes under the drums and between the piers, and the empty roads are on high brows passing outside the piers, with a gradient falling towards the mine.

The 7-ton hopper-bottomed waggons of the main line not being adapted for rope haulage round curves, special waggons have been provided for the incline service; these weigh, when empty, three tons, and contain 4 to $4\frac{1}{2}$ tons of ore. They have a side door hinged from the top, and discharge into the 7-ton waggons over three tipping cradles at the foot of the incline.

An electric signal is provided by which, at almost any point on the incline, warning can be given to the brakesman, and the trains brought to a stand.

The working of the incline is, throughout, automatic. The full waggons are brought to the sidings on the mine side of the drum pillars, by means of the branch railways already described.

From these sidings each incline train, consisting of eight waggons (about 37 tons net load), passes out by gravitation between the drum pillars, where it is hitched on to the cable, and lowered. On arriving at the bottom it is unhitched by hand, and runs down a falling gradient to a back-shunt, whence it returns by a reverse grade to one of the three tipping cradles

already mentioned. These are balanced so that the weight of the loaded waggon is made available to cant the table to the tipping angle; and a counterbalance, in excess of the weight of the empty waggon, serves to return it to its normal position; the operation is automatic, and controlled by a hand-brake.

In canting, the catch of the waggon side-door strikes against a stop which lifts it, and the contents are discharged into a shoot with two mouths, closed at their lower end by shutters, worked from a platform above.

The main line trucks are below, and pass (on a falling gradient) under the shoots, the shutters regulating the quantity of ore for each.

The incline waggons, as they are tipped, pass from the cradles, and are coupled up, and when the empty train is ready, it runs forward to the foot of the incline, where it is attached to the cable and returns to the mine.

On arriving at the top, the empty train passes over the high brows, and is there automatically disengaged from the rope-shackle by means of an inclined surface acting on a lever placed on the leading waggon, the cable dropping down to the lower roads, ready to be attached to the next full train.

This allows of the empty waggons being brought with sufficient speed over the brows to run, without further handling, into sidings, where they are formed into double trains, and hauled by locomotives to the various quarries and loading places.

The present daily tonnage brought over the incline averages 78 trains, or 2850 tons. The maximum day's work has been 3629 tons.

The roads at the foot of the incline are connected with the main line to Luchana, so that goods and materials can be sent direct from Luchana to the mines and *vice versâ* without transhipment. The rolling stock in the Matamoros service is brought down in this way for heavy repair.

The foot of the incline is connected also with an ore-stocking gantry, so that when steamers are scarce, ore can be tipped to stock, and the mines and the incline kept regularly working; whilst, on the other hand, at times of pressure at the shipping

staithes, ore can be loaded from stock, in addition to that which is brought down directly to the cradles.

This stocking-place is arranged so that the main line waggons can pass underneath, and be loaded in the same way as those for the calcined spathic ore, described on page 51.

To facilitate discharging to stock from the side-door waggons, the road on the gantry is canted to an angle to allow them to half-empty themselves when the door catches are released.

The number of men employed at top and bottom in the various operations is forty-four.

In Plate XVI. the arrangement of sidings and appliances at the foot of the incline is shown, and Plate XVIII. gives a photographic view of them.

3. *The Endless Chain of the Société Franco-Belge.*—The Société Franco-Belge des Mines de Somorrostro had already, in 1881, established two important inclined planes (described in the author's previous paper) for the service of its large group of "Concha" mines.

But it possesses also several others, lying detached from the main group, and separated from one another by mines worked by other Companies; the nature of the ground, moreover, being irregular, and with considerable undulation.

Hence a separate haulage scheme had to be planned for these mines, and, after careful study, the endless chain was adopted, in preference to wire ropeways, because of:—

(*a*) Its adaptability to the undulations of the ground.

(*b*) The readiness with which branch lines can be extended in different directions.

(*c*) The very small cost of working.

(*d*) The large limit of variation permissible in daily working, by altering the speed of the chain, and the space between the tubs.

A skeleton plan of the chain road and its ramifications, as at present established, will be found in the general map (Plate V.). The total length is now 3000 metres (2 miles).

The extreme difference of level between the highest point of the line (at Mine Sol) and the arrival station at the Cadegal terminus of the Company's railway is 802 feet (244·6 metres). The maximum gradient is 29·5 per cent.

The movement is automatic, in spite of counter gradients on certain sections; and, indeed, it is necessary to control the *vis viva* by means of brakes and regulators.

The hand-brakes are only used to stop the chain, the speed being regulated by fans attached at certain angle-stations to the shaft of the sheave carrying the chain round to the new alignment.

These regulators are similar to the air-brakes used on inclined planes; but, as the latter revolve at a higher velocity than would be convenient for the relatively slow speed of the chain, and as gearing to counteract them would be too complicated for the rough nature of the work, the ingenious device has been adopted of making the fans revolve in tanks that can be filled more or less with water, the speed being regulated easily by the greater or less immersion of the blades.

Plate XIX. is from a photograph representing an angle station on the penultimate section of the chain, and where it passes close to the "Concha" Station of the Orconera Company's railway, whence an excellent view is obtained of the working of the chain road, and of the manner of separating the tubs containing rubbish from those containing ore, the former running off to the spoil bank, and the latter following on to the next section of the chain; the whole operation at this point only occupying two men.

The ordinary speed of the chain is 1 metre 50 centimetres per second, but it has worked up to 2 metres per second without inconvenience.

The size of the chain is 22 millimetres (9·82 kilogrammes per metre) on all the sections, except that nearest the arrival station; there it is 26 millimetres (14 kilos per metre), on account of the greater tension on that section.

At a speed of 1 metre 50 centimetres, and with tubs spaced 25 metres apart, from 2500 to 2600 tons of ore can be carried per day, in addition to a certain quantity of rubbish. The usual daily average is, however, much less.

The tubs are of timber, and carry 900 kilos of ore.

At the arrival station of the chain, situated at the western extremity of the ore-stocking place in the Company's railway

terminus at Cadegal, these tubs are brought on to tipplers, and transfer their contents into hopper-waggons, which travel on the gantry built over the stocking platforms. These hoppers are worked by an endless chain, to which motion is communicated from the pulley-shaft of the last station of the main chain-road. The rate of their speed to that of the main line is as 1 to 3, and their capacity therefore as 3 to 1. They discharge through bottom doors into the main line mineral trucks direct, or to stock at such point on the gantry as may be desired; their operation is almost automatic, and occupies only one man to regulate the point of discharge.

Plate XX. gives a general view of the Cadegal terminus, showing the arrival station of the chain, and the operation above referred to, of transferring the ore to the stocks.

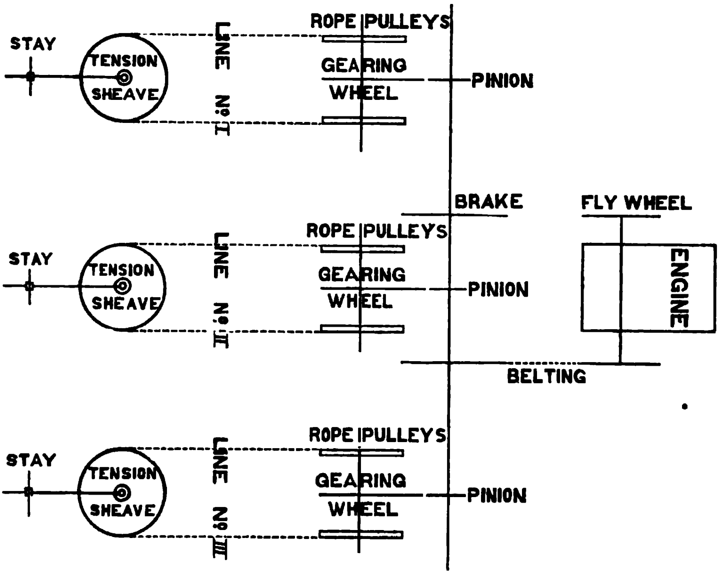
The total quantity of ore carried by the chain in first half of 1896 was 152,000 tons, and of rubbish 33,000 tons.

4. *The Aërial Ropeways (Hodgson System) of the Somorrostro Iron Ore Company.*—These ropeways, which transport the mineral from the Company's mines Union and Amistosa, in Matamoros, to the Arcocha Station of the Deputation Railway, have been greatly extended since they were described by the author in 1882; new lines have been built, and important improvements have been carried out, especially in the saddles by which the buckets are suspended from the rope. These formerly were lined with indiarubber, and slipped to such an extent in rainy weather as seriously to detract from the efficiency of the ropeway (and, indeed, of the Hodgson system itself).

The present saddles, which have now been successfully in work for some years, are lined with wood, and the two extremities carry two toggles of steel, which catch between two strands of the cable, and give a firm grip, so that the saddle holds even on gradients of 28 per cent. (1 in 3·6), and in all weathers.

There are now three complete and independent groups of ropeways, each composed of three separate lines. Of these, one group is for the Union Mine, and two (six lines) are for the Amistosa. Each group is started by a stationary engine, requiring 6 to 8 horse-power for the purpose.

The accompanying diagram shows the installation at the receiving station for one group of three lines:—



The total length from Mine Amistosa (the more distant of the two) to Arcocha is 2835 metres, of which about 500 are against the load. The average gradient is 23 per cent., and the total fall from mine to receiving station is 355 metres (1164 feet).

The lines are supported by wooden trestles, some of them of great height, one being 52 metres (170 feet) where it crosses the Orconera Company's main line of railway at the sixth kilometre from Luchana.

The buckets are of iron, and contain 180 kilogrammes ($3\frac{1}{2}$ cwt.) of ore.

The cables are of steel wire 25 millimetres (1 inch) in diameter, manufactured by Mr. F. W. Scott of Stockport. Their tensile strength is 40 tons, and their average life 125,000 tons; they last from eighteen to twenty-four months.

The buckets are loaded by hand from stocks at the mine, and are tipped to stock at the receiving station, or into small waggons for direct loading into railway trucks.

The average daily quantity of ore carried by one line is 255 tons, and the maximum 300 tons in ten hours.

In 1895 (315 working days), the various groups carried the following quantities :—

		Tons.
Mine Amistosa	Group No. 1, built in 1874	247,693
	,, ,, 2, ,, 1893	249,011
Mine Union	,, ,, 3, ,, 1872	242,045
		738,749

The labour employed is as follows :—

To *each* line at starting station and loading places	20
,, ,, at intermediate stations	2
,, ,, at receiving terminal to receive buckets	3
,, ,, ,, ,, to unload to stocks	2 to 6, according to distance.

The accompanying photograph (Plate XXI.) will afford some idea of the magnitude and completeness of this remarkable network of aërial ropeways.

5. *The Aërial Ropeways of the Exma-Diputacion Provincial de Vizcaya.*—These are two in number, for the service of the demasias "San Antonio" and "Ser" respectively. They both terminate at the station of Ortuella, on the Provincial Railway.

They are single line ropeways on the Bleichert-Otto system, with double fixed ropes on which the buckets travel suspended by hangers and saddles, the motion being communicated by an endless rope, to which the buckets are attached by Pohlig patent clips. The lines are automatic throughout, and are worked from the brake stations.

Lines.—The "San Antonio" ropeway, which is the more important of the two, was opened in June 1892; it is 1729 metres in length, and the total fall, from mine to arrival station, is 144 metres, divided into two gradients, one of 1 in 41 for 700 metres at the top, and the other of 1 in 8, for the remaining 1029 metres. On leaving the mine, the ropeway passes through a tunnel to avoid passing over a hill, and is thus laid on a downward grade throughout its entire length. The trestles supporting the ropeway are of timber, and are spaced 35 metres (115 feet) apart.

The loading station at the mine is of the usual description, the ore is stocked in bunkers with sliding doors, through which the buckets are filled as they pass round from the empty to the full line.

Cables.—The dimensions of the cables are:—

Fixed ropes,	full line . .	38	millimetres	(1·49 inch).
,,	empty line .	30	,,	(1·18 inch).
Hauling rope (endless) . .		20	,,	(0·78 inch).

Buckets.—The buckets are of iron, and the capacity of each is 500 kilogrammes of iron ore, but they are usually loaded with 480 kilos. They are spaced 43 metres apart on the hauling rope; the speed at which they run is about 6 feet per second.

The total quantity of ore brought down in 1895 was 142,000 tons, and the greatest quantity in one day (of twelve hours) was 914 tons. This is remarkable work for a single line.

The "Ser" ropeway was opened in July 1895; it is 1338 metres in length, and is of rather lighter construction than that of the "San Antonio," but in other respects is very similar. The daily average quantity brought down is 350 tons, the maximum being 750 tons (in twelve hours). The total fall from the mine to arrival station is 135 metres (443 feet).

Other Subsidiary Haulage Systems.

The author regrets that space forbids more than a brief reference to many other interesting haulage installations in the district, such as:—

Mining Railways.—Those of the Société Franco-Belge in Concha Mines, 1100 metres in length and of 1 metre gauge.

The "Manuelas" Railway of the Luchana Mining Company, 2 miles in length, 2 feet 6 inches gauge.

The Salve Railway of Don Fernando Alonso & Company (described in 1882).

The tunnel, railway, and underground workings of Mine Linda in Matamoros (Messrs. Allende & Seebold).

The inclined planes of the Société Franco-Belge (described in the author's paper, 1882).

Engine Planes and Inclines.—The engine plane of the Parcocha Iron Ore Company, the largest in the district, worked by a hauling engine 120 horse-power, for the removal of rubbish from the Parcocha Mine and Demasia.

A nearly similar plane for the same purpose at Mine Union of the Somorrostro Iron Ore Company, Limited.

The engine-planes of Mr. Joseph MacLennan at the Rubia Mine.

The railways and inclined planes of Messrs. Victor de Chavarri, and Pedro de Gandarias, at their Ollargan Mines.

The Endless Chain of the Urallaga Company in Galdames.

Aërial Ropeways.—The Hodgson ropeways, some of them 3 kilometres in length, of Messrs. Echevarrieta & Larrinaga, and Larrucea & Lopez, for the Catalina and San Antonio Mines in Sopuerta; that of Mr. F. MacLeod for the Elvira Mine at Galdames; and several others.

B.—Railway Transport to the Bilbao River, and Shipment.

The map (Plate V.), shows the various shipping places, and the railways connecting them with the mines, or with the various subsidiary haulage systems to which reference has been made. The mines just above Bilbao, being situated in the hills that rise on the other side of the river Nervion, send down their ore by inclined planes, wire ropeways, and shoots to the riverside, where it is transferred to lighters, for shipment by hand or by floating crane, at a convenient point below Bilbao (see Plate XXII.).

The Ollargan groups, so greatly developed within recent years, are now connected by the Northern Railway of Spain, and the Bilbao and Portugalete Railway (both of 5 feet 6 inches gauge), with the river at Olaveaga, about three miles below Bilbao, where a stocking depôt has been formed, and the ore is shipped at three staithes built for the purpose. The daily rate of shipment is from 500 to 1000 tons, according to stocks.

From Iturrigorri the ore is mostly carted to the riverside near Olaveaga, and shipped by hand.

Castrejana (Mine Primitiva) continues to be served by the old Hodgson ropeway (3160 yards long) that brings the ore to a small depôt and shipping place at Zorroza.

The mines opened out in recent years in the valley of the river Cadagua and in Alonsotegui and Gueñes, are chiefly served by the new railway opened for public traffic in 1890 to Valmaseda, which has established a small shipping place at Zorroza, about half a mile above Luchana.

This railway to Valmaseda is extended now to the provinces of Leon and Santander, and has in construction a line from Zorroza to Bilbao, so that when complete it will form a most important network. One mine, however (the Anton), has an endless rope haulage of its own to the river at Olaveaga.

The remaining groups find their outlet by one of the five following railways, named in the order in which their shipping places are situated on the river, following the direction of the stream. All these railways have termini and shipping places on the left bank of the river Nervion (known in its lower reaches as the "Bilbao" river).

1. The "Orconera and Luchana" Railway of the Orconera Iron Ore Company.
2. The "Regato" Railway of the Luchana Mining Company, Limited.
3. The "Franco-Belgian" Railway of the Société Franco-Belge des Mines de Somorrostro.
4. The "Triano" Railway of the Provincial Deputation.
5. The "Galdames" Railway of the Bilbao River and Cantabrian Railway Company, Limited.

With the exception of No. 4, built by the Provincial Deputation of Biscay, the above are private lines and were built primarily for the transport of the ores of the respective Companies that own them; but they have extended their operations to the carriage of ore for other mining enterprises.

The Orconera Iron Ore Company's Railway is 12 kilometres ($7\frac{1}{2}$ miles) in length from the river terminus at Luchana to that of the mines at Gallarta, the latter being 656 feet above sea-level. The rise is nearly continuous, at a gradient of 1 in 44, and 53 per cent. of the line is sharply curved; 120 metres (394 feet) being the ruling radius.

There are twelve tunnels, one river bridge, and several high

retaining walls. The excavation is mostly in rock, and the earthworks are heavy.

At 9 kilometres ($5\frac{1}{2}$ miles) from Luchana, and 525 feet above sea-level, is the Orconera Station (already referred to at pages 50 and 58). This is the principal collecting station on the line, and to it converge the Orconera, the Espinal, and the Carmen inclined planes, and the branch railway (3 kilometres in length) from Gallarta and the Concha No. 1 Mine. At this station are also the calcining kilns (page 50).

The accompanying plan (Plate XVI.) and the photographic view (Plate XVIII.) will afford an idea of the general arrangement of the station yard, the sidings in which are, as far as possible, laid out for working the loaded trucks by gravitation. On a fairly busy day in summer about 5000 tons of mineral are handled in this station, besides receiving and distributing the empty waggons, and the goods and material trains sent from Luchana.

The Concha Station on the Gallarta branch serves for the mine of the same name, worked by the Orconera Company, one of the richest Rubio mines in the district for its area. The railway enters into the mine by a tunnel (Plate XXIII.).

From this station can be seen many interesting examples of haulage; the Franco-Belgian endless chain, the inclines of the Julia and Adela Mines (Messrs. Chavárri & Arana), the incline and railway of the Salve; while below, in the valley, lie the stations of Ortuella (Provincial Deputation) and Cadegal (Franco-Belge).

Gallarta, 12 kilometres (656 feet) above sea-level, the terminus of the railway, has lost the activity that characterised it in the old Campanil days. The tunnel still enters the Cesar Mine, but the latter serves merely to indicate what *has* been. Still it is worth a visit for the interesting geological sections that may even yet be seen, though now they are nearly buried by rubbish tipped from the workings.

From Gallarta, looking across the valley to the northward, a fine view of the Hospital Minero is obtained; below lies the valley of Somorrostro, the principal scene of the last Carlist war; whilst, winding through the valley, the Sestao and Galdames Railway of the Bilbao and Cantabrian Company may be observed.

In the distance a glimpse is obtained of the shipping place at Poveña of the Vizcaya Santander Mining Company.

The line is double from Luchana to Orconera, and is laid throughout with steel rails 56 lbs. to the yard. It was opened in 1877.

The following is a list of the rolling stock of the Orconera Company:—

Main-line locomotives	15
Shunting locomotives	8
Main-line 7½ ton iron and wood waggons	570
Ballast waggons	30
Goods waggons	17
Passenger coaches	5
Incline-plane waggons	300
Mining waggons	560

From Luchana a branch line, 1500 metres in length, runs to the steelworks of the Sociedad de Altos Hornos, which there receives the mineral direct from the quarries.

At Luchana are the offices, manager's and agents' houses, repairing shops, laboratory, and shipping staithes.

The shipping appliances consist of four staithes, normal to the river, spaced 318 feet apart, and approached by embankments laid with self-acting gradients.

There are two discharging wharves for coals and materials. The moorings consist of five buoys in mid-channel, and eight dolphins between the staithes, besides the usual bollards on the quay.

The total river-frontage is 1650 feet, formed by a neat rubble river wall, with ashlar coping, protected at the foot by sheet-piling from the river scour. The depth of water in front of the staithes at low spring-tides is 19 feet.

The Orconera Company's shipping staithes have often been described. They differ from all others in the river, and were designed (by the late Mr. J. P. Roe of Consett) to suit the limited headway from high-water to rail-level.

Each staith consists essentially of a swing-platform of four wrought iron girders projecting from a timber tower, founded on piles, to which it is attached at its landward end on trunnions, being raised and lowered by a hand-chain passing from the outer end over drums, and counterweighted like a drawbridge. The

rails forming the waggon-way are laid on the platform and secured to the centre girders, and the whole is floored with three-inch planks.

Suspended from an open-mouthed hopper, on the underside of the platform, is a telescopic trunk-shoot, in four sections, sliding one on the other, and closed by strong bottom-doors. The operation of loading a light vessel, berthed alongside the staith, is commenced by running up the telescopic-trunk and closing the doors. The railway waggon comes on to the platform by gravitation, and is brought to a stand over the hopper, and its contents are discharged into the trunk, which is then lowered into the ship's hold; the doors are then opened by releasing a catch, and the mineral falls gently over the bottom. The trunk is then run up for another charge by means of counterweights, sufficient to lift them when empty, their ascent being controlled by the brake. The contents of four or five waggons are put thus into the ship, after which the mineral is discharged through the trunk with the doors open.

This system of loading saves trimming, and preserves the skin and tank-tops of a steamer from injury through the unbroken fall of mineral.

The waggons pass on and off the staith by gravitation. The maximum tonnage loaded at one staith in thirteen hours was 3017 tons. The maximum in twelve hours with three staithes was 5375 tons. The number of men employed at each staith is six.

Plate XXIV. shows a general view of the four staithes and river wall. Plate XXV. is an enlarged view of staith No. 3, at work.

The Regato Railway of the Luchana Mining Company is 4½ miles in length from Luchana to the village of Regato (272 feet above sea-level). The ruling gradient is 1·8 per cent. in favour of the load. The line is single, laid with 44 lb. steel rails, gauge 1 metre.

The Company's shipping staith is at Luchana, just below those of the Orconera Company. It is at a higher level than any other, and this enables the inclined shoot for loading the vessels to be adjusted to the level of the tide and the height of the ship out of water.

The waggons contain 4 tons of ore, and discharge by an end door hinged from the top, over a tipping cradle.

The waggons pass to and from the staith by self-acting gradients.

The railway having only recently resumed work after two years' stoppage, the data available do not correctly represent its operations, but the normal rate of working is about 160,000 tons per annum.

The rolling stock consists of 4 locomotives and 143 4-ton waggons.

The terminus at Regato is connected with the mines by two inclined planes and a 2 feet 6 inches gauge railway. Other mines are also connected to this railway by wire ropeways.

The Railway of the Société Franco-Belge is a single line of 4⅝ miles in length; its terminus is at Cadegal, not far from the Ortuella Station of the Provincial Railway. Instead of climbing up the mountain, like the Orconera and Galdames Railways, it keeps to the valley, and the ore is brought down to it by automatic hauling appliances already described. It is therefore nearly level, the total rise being only 91 feet, and nearly straight, so that the traffic conditions are excellent. The gauge is 1 metre, the rails 48½ lbs. per yard.

The rolling stock consists of 6 locomotives and 250 8-ton mineral waggons, discharging by bottom doors. The general arrangement of the waggon is well planned, especially as to the mode for releasing and shutting the bottom doors and the facility of discharging the ore.

The river terminus is at Luchana, about a quarter of a mile below that of the Luchana Mining Company. The shipping appliances consist of three staithes normal to the river, with inclined shoots; two are 275 feet apart, the third 265. The approaches are arranged with self-acting gradients.

The number of men employed at each staith is six; the loading capacity of each staith is 2000 tons per day; 1490 tons have been loaded in six hours, but the average rate of shipping depends more on the regularity with which the staith can be supplied.

The Triano Railway of the Provincial Deputation is eight miles in length, and, like that of the Société Franco-Belge, alongside

which it runs for some distance, keeps to the valley, and is nearly level throughout. The gauge is 5 feet 6 inches, and the rails are of steel 68½ lbs. per yard.

This line has been in operation since 1865. It is the property of the Provincial Deputation and an important source of the provincial revenue, as it is the principal medium of carriage from the mines, and 33 per cent. of the mineral now exported passes over its staithes.

For many years its terminus was at Ortuella, 5½ miles from the river, but in 1890 it was extended to San Julian de Musques at the end of the Somorrostro district; principally to serve the Petronila, Confianza, and other mines in that neighbourhood. In addition to the mineral traffic, it carries goods and passengers; and for this purpose has a junction with the Bilbao and Portugalete Railway at the station of El Desierto. Plate XXVI. gives a view of Ortuella, which still is the principal collecting station for ore; and where a permanent loading gang of about 300 men are employed by the railway. Plate XXI. shows the intermediate station of Arcocha (2½ miles from the river terminus), where the arrival-station of the Somorrostro Iron Ore Company's wire ropeways is established, and where ore from that Company's Matamoros Mines "Union" and "Amistosa" is received and loaded into railway trucks for shipment.

The rolling stock, consisting originally of 1 locomotive and 22 waggons, now numbers 15 locomotives, 89 8-ton iron waggons, and 312 6½-ton wooden waggons; all end-tipping.

The river terminus and staithes are at San Nicolas (Plate XXVII.), about half a mile below those of the Société Franco-Belge, and three miles from the entrance to the river.

There are now seven tips in all, four of which have been added in recent years. The ore is loaded into vessels from the tip-waggons through incline shoots. Some of the older staithes are low and cramped for room; but in spite of all disadvantages good despatch is given to steamers; on 6th May of this year 7448 metric tons were loaded into vessels.

The Sestao and Galdames Railway of the Bilbao River and Cantabrian Railway Company (formerly the Bilbao Iron Ore Company) is the longest in the district. From its river ter-

minus at Sestao to that of the mines at Galdames it is 22 kilometres (13·5 miles) in length; and it rises for the first 7 kilometres at a gradient of 1 in 45, till it reaches Santa Juliana, after which it continues nearly level. The line is double to Bodovalle. The gauge is 3 feet 9 inches, and 55 per cent. of its length is on sharp curves, many of 80 metres radius.

Next to the railway of the Provincial Deputation, this is the earliest established. It was opened in 1876 for the development of the Company's mines at Galdames, but has subsequently acquired a considerable outside traffic from others.

At Bodovalle (7 kilometres), Pucheta (11 kilometres), La Balastrera (10 kilometres), and El Cerco (19 kilometres), there are stations with large depôts of ore.

In recent years this Company has extended its operations to important groups of mines in the Sopuerta district (Catalina, Rebeñaga, San Antonio, &c.), which bring their ore to the station of El Cerco by means of wire ropeways, some of which are more than 3 kilometres in length. It possesses the following rolling stock: 7 main line locomotives, 4 shunting locomotives, 525 main line mineral waggons, 14 ballast waggons.

The shipping appliances at Sestao consist of a pier parallel to the river, and a staith normal thereto, added in the year 1884. The pier, as originally erected, had berths for four ships, but in consequence of the continually increasing length of steamers of late years, the loading berths have been reduced to three; improvements having been effected in them, so that a greater quantity of ore can be dealt with now at three tips than formerly at four.

Owing to the strong ground-swell at the entrance to the river, difficulties in mooring and making fast were encountered, and for many years caused inconvenience during freshets in the river. They have been overcome by allowing the shoots to swing longitudinally, and accommodate themselves to the movement of the steamer.

The greatest day's work at all staithes (4) was 4599 tons, and the greatest railway transport day was a total movement of 5375 tons.

The offices, residences of manager and sub-manager, engine-sheds, and repairing shops are at Sestao, and a branch line about

a quarter mile in length runs to the blast-furnaces of the Sociedad "La Vizcaya," which thus receives its ore direct from the Galdames mines, leased by it from the Bilbao and Cantabrian Company.

The following table gives the quantities of iron ore carried and shipped by the local railway companies during 1895 and the first six months of 1896:—

	1895.	First Half, 1896.
	Metric Tons.	Metric Tons.
The Provincial Deputation	1,409,338	848,954
The Orconera Iron Ore Co., Limited	1,245,890	698,951
The Bilbao and Cantabrian Railway Co.	862,785	469,633
The Société Franco-Belge	450,805	334,555
The Bilbao and Portugalete Railway Co. (Mineral of Messrs. Chavarri & Gandarias)	193,135	95,473
The Cadagua Railway Co.	20,136	7,609
The Luchana Mining Co.	nil.	3,517

BILBAO DISTRICT.

General Remarks.

In Table D will be found the yearly exports of iron ore from the Bilbao River from 1882 to 1895 inclusive. The total quantity shipped in the last-named year was 4,214,000 tons, of which 3,122,000 tons went to British ports. The exports of the present year bid fair to reach 5 millions of tons, and will be in that case the highest on record.

The approximate output of the whole district from the commencement of modern mining operations in 1860 or thereabouts to 31st December 1895 has been about 68 millions of tons (Table D), and it may be roughly computed that about half that quantity yet remains unworked. It is, however, not safe to prophesy. We have been so often told that Bilbao was *in extremis;* yet year after year the output is maintained, and even increases. Naturally this cannot go on for ever, and, the higher the annual output, the shorter will the life of the mines be; nevertheless it may reasonably be expected that Bilbao will, for several years yet, continue to be a most important source of iron ore supply.

THE "VIZCAYA" BRIDGE AT PORTUGALETE.

This bridge, which connects the town of Portugalete with the village of Las Arenas, at the mouth of the river Nervion, though not coming strictly within the scope of this paper, yet merits attention, both on account of its novel design, and of the success which has attended its operation.

The problem to be solved was to provide a means of communication for passengers, cattle, and vehicles, without interfering with the passage of ships, and at a moderate cost. This is effected by suspending a capacious trolley from an overhead superstructure, supported by lofty towers on either side of the river; the trolley being hauled to and fro by wire ropes, driven by a steam-engine fixed in one of the towers on the Las Arenas side of the river. In fact, in principle it is a span of an Otto ropeway on a large scale, adapted to public traffic.

The clear span between the towers is 162 metres (531 feet), and the height of the roller path from which the trolley is suspended to high-water (spring tides) is 45 metres (147 feet). The height of the towers is 62 metres (203 feet), and the versed sine of the curve of the main suspension cables that support the platform is 17 metres (55 feet). The total weight of the iron structure is 600 tons, of which the cables (steel) weigh 110 tons. The cost was £20,000.

The weight of the trolley is 14 tons when empty (including in this weight that of the suspending cables and roller gear), and it is constructed to carry 30 tons of live load.

The engine is 25 horse-power, of which 7 to 9 horse-power only are required to drive the trolley on ordinary occasions. In high winds the entire power is sometimes needed.

The bridge has a large margin of strength against wind-pressure, and even in the severe winter gales the vibration is insignificant. The foundation of the towers are carried down to the solid rock below the bed of the river.

The work was commenced on 1st June 1890, and the bridge was opened for public traffic on 27th July 1893. It is the property of the Vizcaya Bridge Company.

The author of the project is Don M. Alberto de Palacio, architect, of Bilbao, and the details were worked out, and the bridge

constructed, by Mr. Ferdinand Arnodin in his works at Chateaumeux-sur-Loire, and erected under his personal supervision.

The photograph (Plate XXXIII.) gives a view of the bridge as it appears from the Portugalete iron jetty, looking up the river.

THE PORT.

In no way has the progress of Bilbao been better exemplified than by the improvement effected in the port during the last fifteen years.

In 1881 a sand-bar existed at the mouth of the river that only allowed the passage of vessels drawing from 15 feet to 15 feet 6 inches during about four days of spring tides, but if bad weather prevailed the port was practically closed for the exit of loaded ships; so that it was no uncommon thing to see fifty to sixty steamers neaped in the river for a fortnight at a time, and even then having to lighten cargo before being able to cross the bar.

The works, then described by the author, have been successfully carried out by the enterprising Harbour Improvements Board (Junta de Obras del Puerto), under the able direction of its engineer, Don Evaristo de Churruca.

The principal features of this work are a handsome training jetty, 800 metres in length (on the left bank of the river-mouth), the straightening in places of the river channel, and the dredging of about 6½ millions of cubic metres over a length of 14 kilometres of river-bed.

The effect of these improvements, completed in 1887, has been, that at high-water of all ordinary spring tides, steamers drawing 22 feet, and at neap tides 18 feet, can pass out freely; and freights to the British Channel have been reduced from 10s. 6d. to as low as 4s. And moreover it has rendered possible the establishment on the Bilbao River of a ship-yard, with marine engineering works and ordnance factory (known as the "Astilleros del Nervion"), that has turned out three first-class protected cruisers of 7000 tons each for the Spanish Government.

The river is illuminated at night by electric light between Portugalete and El Desierto, for two hours before and two hours after high-water, when ships are allowed to enter and leave the port.

In 1881 the largest single cargo loaded by the Orconera Company was of 1690 tons (s.s. *Cyfarthfa*); in 1895 it was of 5380 tons, loaded into the s.s. *Noviembre*, which sailed from the river on 23rd August 1895 drawing 22 feet 10 inches of water aft.

But not content with the improvements already effected, the "Junta de Obras" determined to carry out the larger scheme for a maritime port, projected many years ago, and reported upon by eminent engineers, amongst them the late Mr. Charles B. Vignoles in 1863, and subsequently by the late Sir John Coode in 1873.

The surveys and plans, prepared by Don Evaristo de Churruca, were approved by the Spanish Government in 1888, and in the following year the works were commenced by the contractors, Messrs. Coiseau, Couvreux-fils, et Félix Allard. They consist of a breakwater 1500 metres in length, on the western side of the bay, protecting the harbour from the north-west gales; and a counter-mole, on the eastern side, of 1100 metres, leaving a free entrance of 640 metres for movement of vessels in and out, this entrance being so aligned that it is protected from the prevailing winds.

The position of these works, which enclose an area of 300 hectares (741 acres) available for the largest ships, is shown on the map (No. 1).

The breakwater, as originally designed, consisted of a rubble and concrete mound, crowned by a superstructure composed of concrete blocks on the external faces, with concrete hearting between them.

Since the commencement of operations, a portion of the superstructure has suffered damage on two occasions from the fury of the gales in the winters of 1893 and 1894, and has necessitated a modification of the original design. Space will not permit of more than a brief description of this; but in the admirable Yearly Reports of Don Evaristo de Churruca will be found full information upon all details of design and construction, and upon the difficulties (inherent to all sea-works) that have been encountered, and, it is hoped, at length overcome.

For those not conversant with the Spanish language, abstracts in English will be found in several volumes of the *Minutes of*

Proceedings of the Institution of Civil Engineers, amongst the foreign papers; and a translation of a portion of Mr. Churruca's Report of 1889 is also given by H.B.M. Consul at Bilbao, Mr. Charles S. Smith, in his Reports for 1895–96. These are published by the Foreign Office, and contain a mass of information on various points of great value to British traders having interests at Bilbao.

By permission of Mr. Churruca, longitudinal and cross sections of the breakwater, as at present carried out, are shown in Plate XXVIII. In these, the relative positions of the new design, and of the work already constructed according to the old one, are shown. The latter will remain as a protection to the new work now being constructed on the inner side of it; and without which protection, this new design, which is of engineering interest as being the first example of its kind, could not have been safely adopted.

The foundation is formed of a rubble mound, discharged from barges and levelled up by divers at a depth of 5 metres under low-water at equinoctial spring-tides. On this foundation a monolithic superstructure is built, in seven-metre lengths, in the following manner :—An iron caisson, 13 metres long by 7 metres wide by 7 metres deep, made on shore, is towed to the site and lowered on to the foundation. Before towing out, it is filled with concrete to a depth of 1·5 metres to ballast it. The caisson is divided into six compartments (see Plate XXVIII.). Into each compartment two sixty-ton concrete blocks, each 4 metres by 3 by 2·5, are lowered by a titan. The water is pumped out, and the interstices are then filled with Portland-cement concrete. The blocks and cement-concrete form one mass (bound together by the iron caisson), whose upper surface is 2 metres above low-water (equinoctial spring-tide). The remaining superstructure, 5 metres in height, up to quay-level, is composed of sixty-ton blocks of Portland-cement concrete, with a hearting of quick-setting cement-concrete. The cement for this proceeds from Zumaya, in the neighbouring province of Guipuzcoa.

In this way a complete seven-metre length up to quay-level is built in four to five days, of which, the placing of the caisson in position, filling it with blocks and concrete, and dressing off everything to the two-metre level above low-water, occupies

from two-and-a-half to three days, which may be considered remarkable work.

At the present rate the whole length of 1500 metres may be expected to be finished by about 1900. Plate XXIX. shows the portion already constructed, according to the new design.

The counter-mole on the eastern side of the bay is well advanced. It is composed of a rubble and concrete block mound, and a superstructure of similar class, but of different dimensions to that for the breakwater.

The plant employed by the contractors in their work is well designed and very interesting (see Plates XXX., XXXI., and XXXII.).

The titans (two in number) for setting the concrete blocks are built by the Sociedad Vasco-Belga at its works near Bilbao. Underneath them is fixed the concrete mixing plant for filling between the blocks in the caissons, and for the hearting of the superstructure.

At Axpe, on the right bank of the river and about three miles from the entrance, are the quarries and contractors' yard, and workshops for making the concrete blocks, also the cranes for handling the blocks and loading them into barges.

All the above plant (including the titans) is worked by electricity.

These harbour works are of peculiar interest to British traders as the bulk of the total estimated cost of one million and a quarter sterling is paid from funds obtained by levying discharging duties on coals and merchandise, and export dues on iron ore. When completed, they will place Bilbao in the first rank as a commercial port and harbour of refuge, but cannot be said to be of much benefit to the mining industry, as all the shipping appliances for loading iron ore are situated in the river, and are already perfected.

MINES WITH INDEPENDENT SHIPPING PLACES ON THE CANTABRIAN COAST.

A.—*IN BISCAY.*

Cobaron and San Francisco.

To the west of the Somorrostro river, and close to the confines of the province of Santander, there are two groups of mines, which, being separated from the general network of haulage, have their outlet at Poveña, on the western shore of the bay, into which the Somorrostro river flows.

The Cobaron group consists of five mines, of which the Amalia-Vizcaina and the Complemento Demasia are those that are at present giving ore.

These mines have been at work since 1882 on Rubio and Spathic ore. Owing to heavy cover, the workings are largely underground. Figs. 7 and 8 (Plate VII.) show cross sections of the strata in Mines San Julian and Amalia-Vizcaina.

They are connected with the shipping place by a metre-gauge railway, three kilometres in length, skirting the precipitous cliffs that overhang the sea at this part of the coast. The gradient falls to the port, and the waggons, each holding 4½ tons of ore, run down by themselves (in trains of eight), being hauled back, empty, by a locomotive.

The San Francisco group is situated further inland, and is connected to the metre-gauge railway by one of half a metre (1 foot 8 inches), 3½ kilometres in length. The mines lie up the mountain-side, and are joined to the small railway by four self-acting inclines.

The exposed position of the shipping place at Poveña rendered it imperative for the arrangement to be such that a steamer could be loaded in a comparatively few hours, and, in the event of a storm threatening, could slip her moorings and make for the open, or for the nearest port of refuge.

The pier consists of a double-storied timber and iron stage, with inclined shoot attached, erected on a masonry pier, and projecting from it to sufficient distance to allow a steamer to be

berthed underneath. The height from lower platform to high-water (ordinary spring-tide) is 52½ feet.

At the shore end is a depôt for 3500 tons of ore, from which the tubs can be loaded at two levels, the object of the double story being to discharge into the ship simultaneously from two levels, and so obtain double despatch.

On the upper story the ore tubs travel in a circle from the depôt to the shoot, and round again to the depôt, avoiding all shunting, so that an almost continuous stream of mineral is poured into the vessel's hold. In this way 2260 tons have been loaded in ten hours.

At Cobaron there is also a calcining kiln, the earliest in the province, built in 1882 of stone, for the spathic ore of the Amalia-Vizcaina, which, when roasted, gives about 53 per cent. Fe (dried at 100° C.).

Ore-dressing plant was also put up to deal with a portion of the spathic ore, containing 10 per cent. of galena, but this has been at a standstill for many years.

The mines, railways, and appliances briefly described are the property of the Vizcaya Santander Mining Company, and were designed and carried out by Mr. J. MacLennan, who holds an interest in that company.

The quantity of ore shipped annually (in 1895, 34,000 tons) is not large, but the installation is of interest, as being the pioneer of others of a similar class on the coast.

B.—*IN THE PROVINCE OF SANTANDER.*

Setares.

About 4½ miles to the westward of the Cobaron group, just described, lies that of Setares, consisting of the Ceferina, Prevision, and other mines, worked by the Setares Mining Company (Compañia Minera de Setares).

These mines had been idle for years, owing to difficulties of transport and shipment. They are situated 3·4 kilometres (2·1 miles) from the coast, and 260 metres (853 feet) above sea-level; the ore-mass consists of Rubio and Vena, with a large proportion of small stuff, and of rather more siliceous nature than that of

Triano and Matamoros. Fig. 9 (Plate VII.) represents a typical cross section.

The workings are open-cast, and the rubbish is systematically removed outside the mine, while the small stuff is concentrated by washing. In this last respect the company is fortunate in having a good supply of water, and a free outlet for the mud to the open sea, both conveniently near. Therefore the washing is effected under more favourable conditions than could ever be hoped for in the Bilbao district.

Washing Plant.—This is situated at Onton, and consists of six trommels, 3·2 metres long by 2·2 metres diameter, mounted in pairs on friction rollers. Each trommel is capable of treating 8½ tons of clays per hour.

The water is raised from the river Onton by centrifugal pumps, the quantity employed per second being 60 litres, and the whole machinery is driven by a horizontal compound engine of 30 horse-power.

The washers being situated at the bottom of a ravine 225 feet below the railway level of the mine, the clays are lowered, and the washed stuff is sent back to the railway, by an inclined plane 550 metres (601 yards) in length, with a gradient of 45 per cent. (1 in 2·2).

The incline tubs hold 2¼ tons; five tubs, containing 11¼ tons of clay, go down each journey, and 10 tons of ore are sent up. The surplus empty waggons go up in alternate trains.

The daily average quantity of clay washed during the past six months has been 600 tons, resulting in 297 tons of washed ore, or nearly 50 per cent. In addition to this, it is estimated that about 120 tons of fine ore escape to the sea in the mud after leaving the washers; and experiments are now being made with a view to saving a great part of this.

The original installation was for 4 trommels, and was supplied by the Humboldt Company of Cologne in 1891. It has since been extended.

Transport.—The relative situation of mines and sea-coast did not permit of transport by railway, or even by railway and inclined plane for the whole distance; therefore, after much study, the following combination was adopted, and has since been successfully executed and operated:—

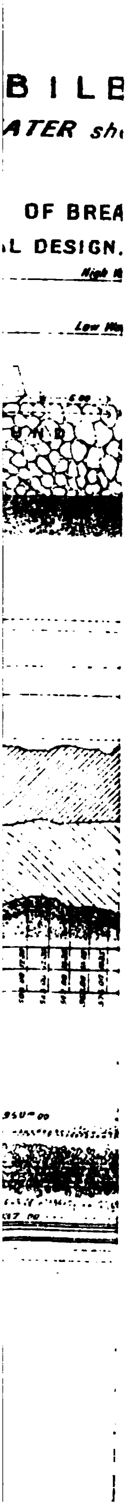

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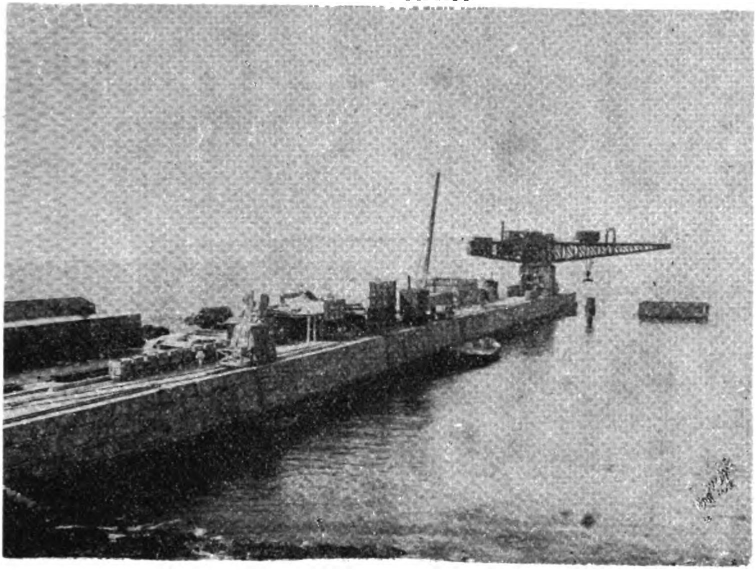
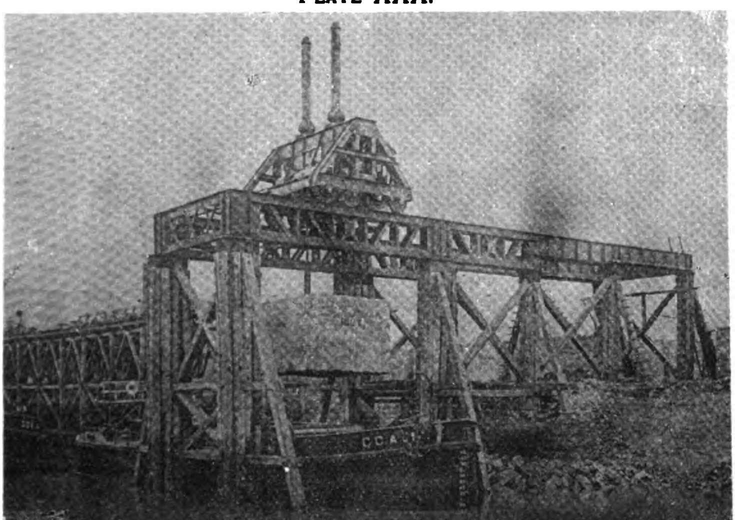
PLATE XXIX.



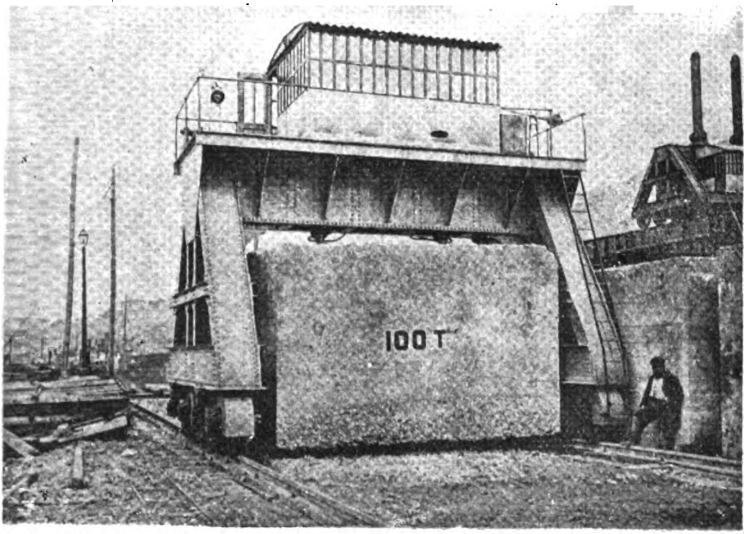
Bilbao Breakwater.

PLATE XXX.



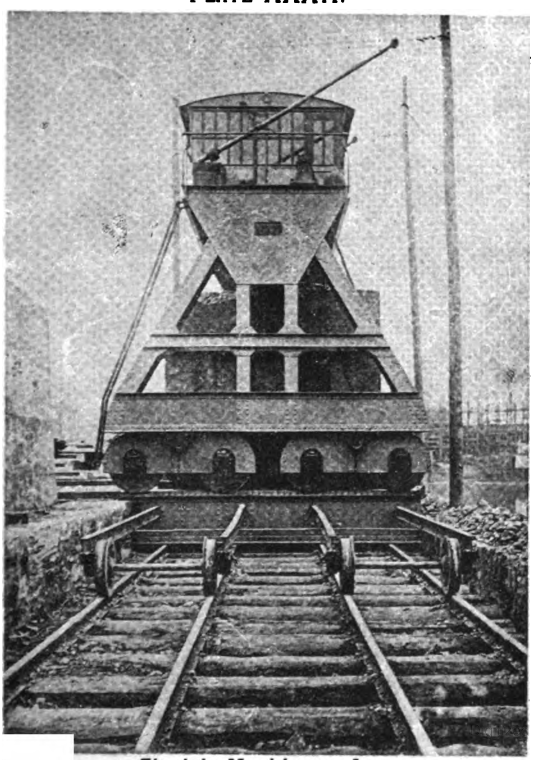
Electric Machinery, Axpe.

PLATE XXXI.



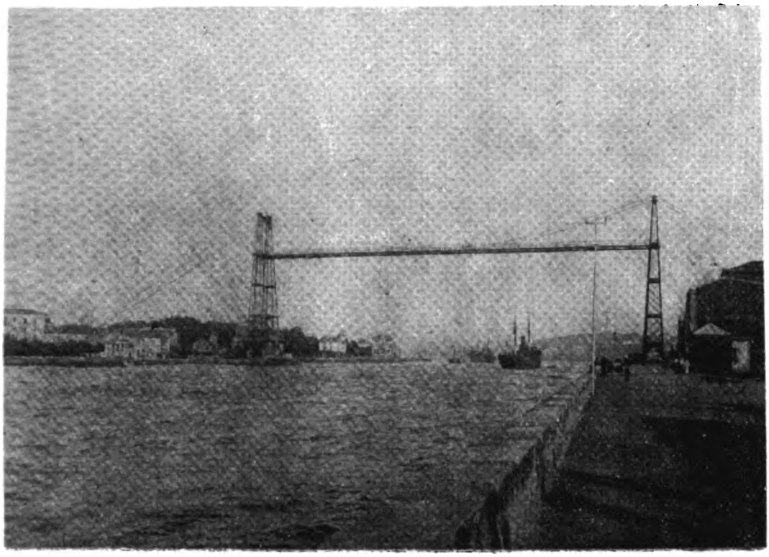
Electric Machinery, Axpe.

PLATE XXXII.



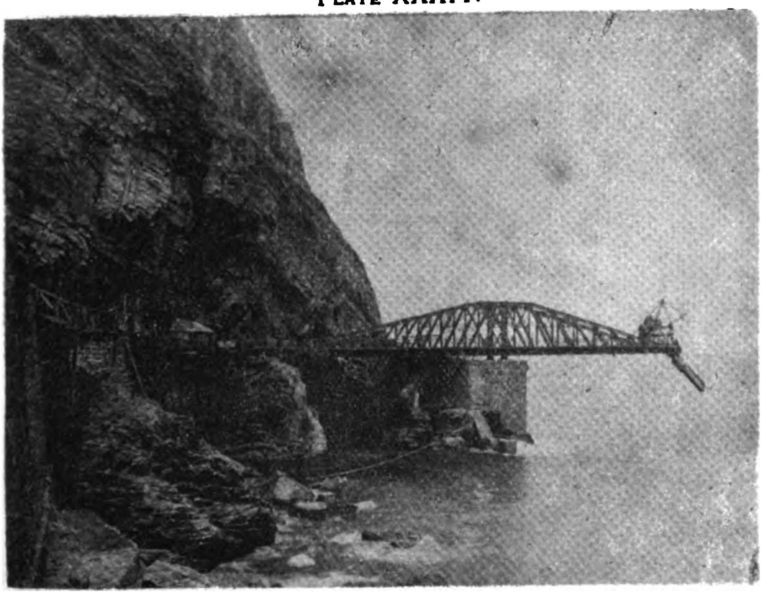
Electric Machinery, Axpe.

PLATE XXXIII.



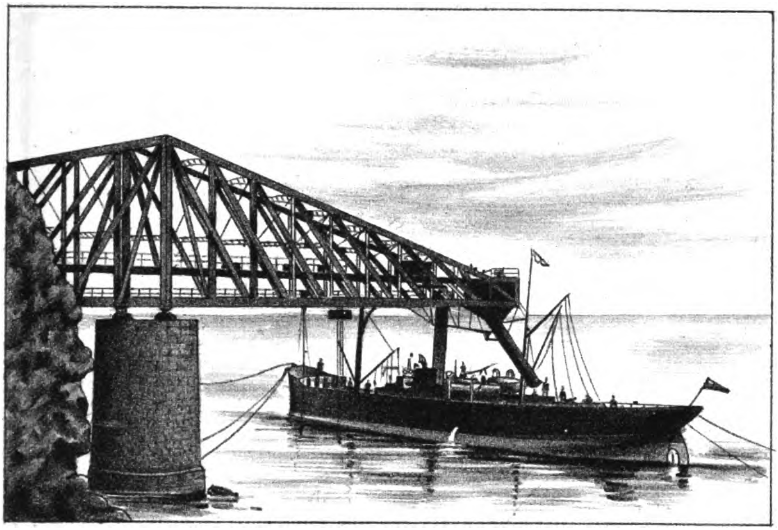
Bridge at Portugalete.

PLATE XXXIV.



Shipping-pier, Salta Caballo.

Plate XXXV.



Shipping-pier, Dicido.

Plate XXXVIII.

Obregon Mines; quarry workings.

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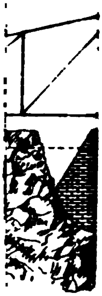
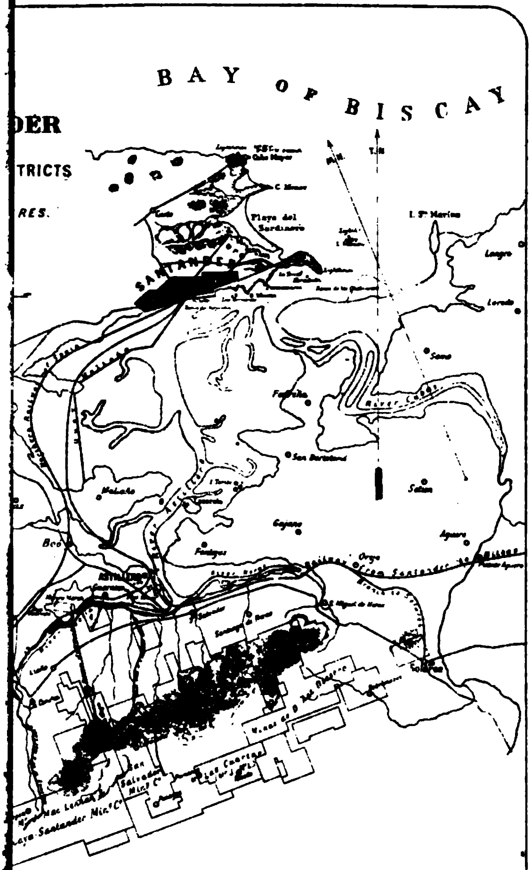
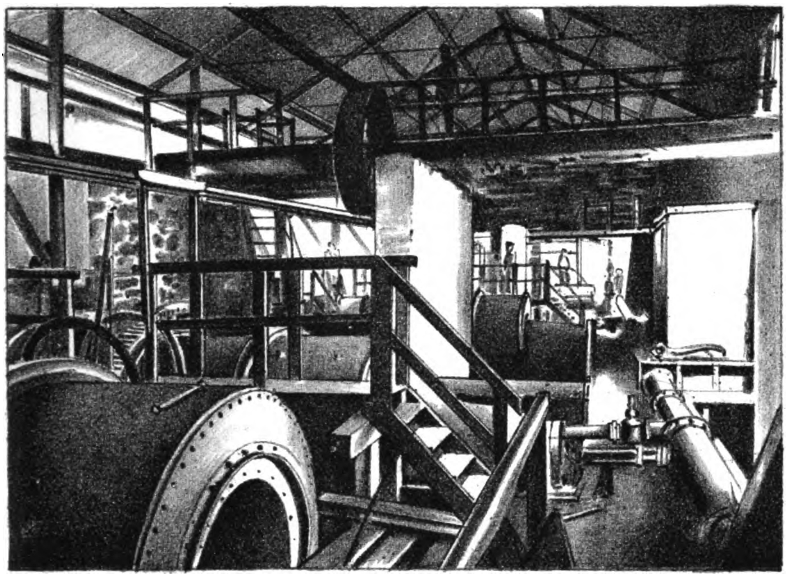


PLATE XXXVII.



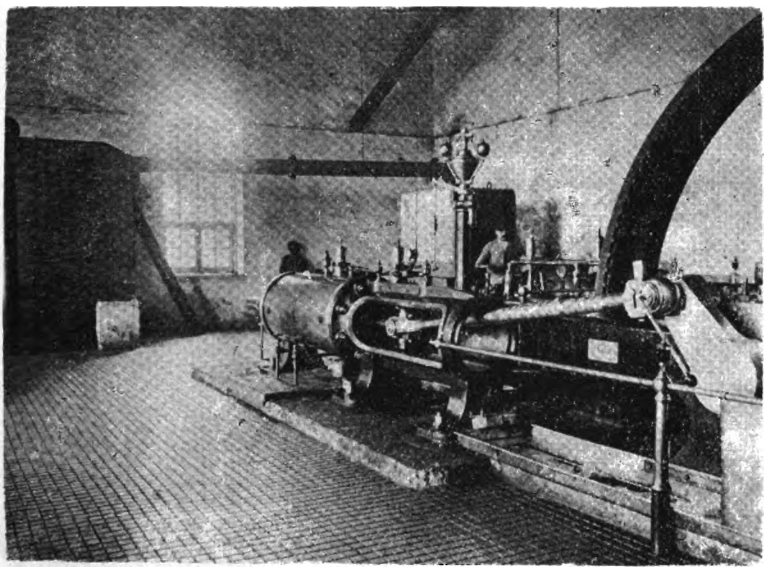
Ballantyne, Hanson & Co. Edinburgh & London.

PLATE XXXIX.



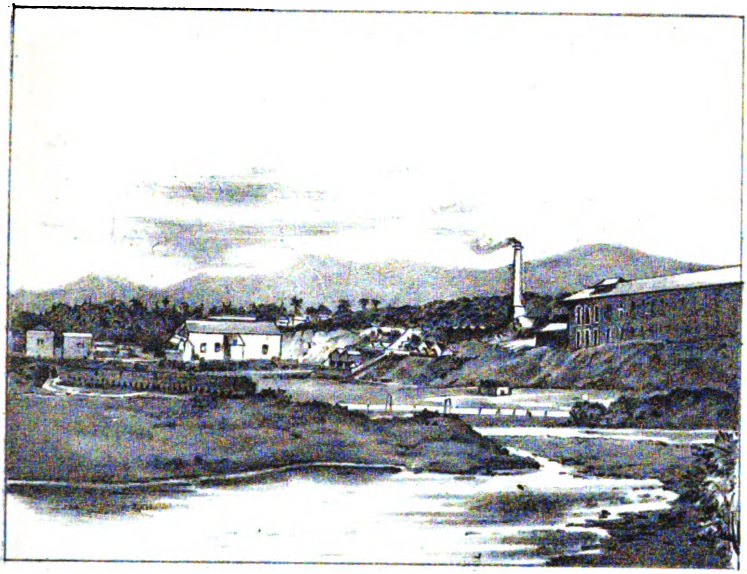
Ore-washing Shed, Solla.

PLATE XL.



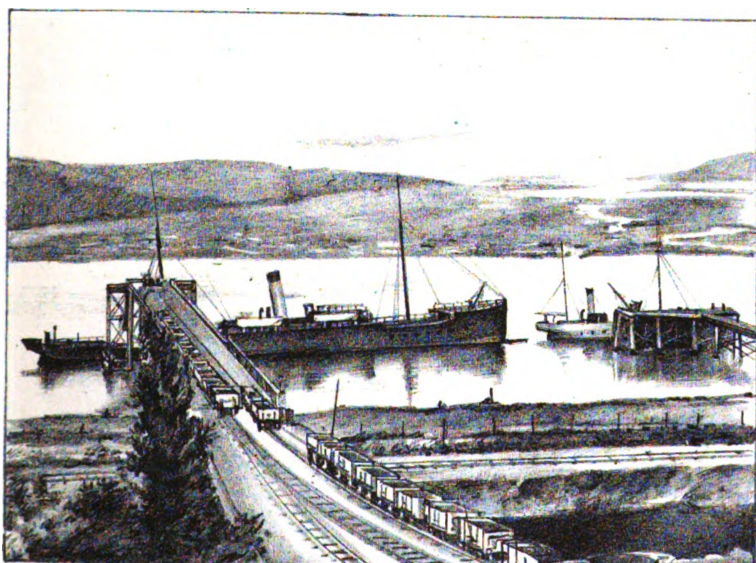
Engine-House, Solla.

PLATE XLI.



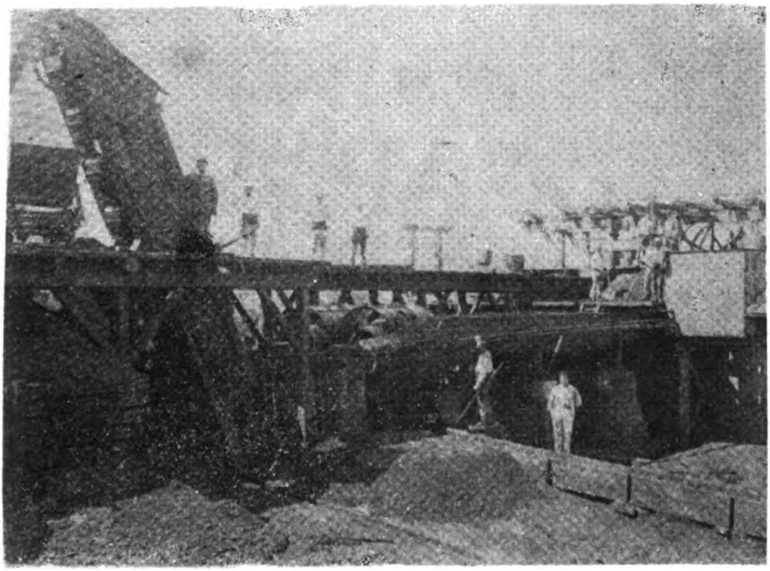
Obregon Mines; washing.

PLATE XLII.



Shipping-pier, Astillero.

Plate XLIII.



Ore-washing.

1st, A railway, $2\frac{1}{2}$ kilometres long, of 0·76 metre gauge, leading by a falling grade of 1 in 100 to the head of an inclined plane.

2nd, An inclined plane, 670 metres long, with 121 metres total fall from brows to foot, and gradient of 1 in 5, delivering the ore to the head of a cage-drop.

3rd, A cage-drop, 55·74 metres (182 feet) in height, which lowers the ore down the face of the cliff to a stocking depôt at the landward end of the shipping pier.

The railway is laid with steel rails, 15 kilos per metre (30 lbs. per yard), and the rolling stock consists of 7 locomotives and 362 waggons, each carrying $2\frac{1}{2}$ tons of ore.

The ore is hauled on the railway in trains of 44 waggons (110 tons net) to the incline, and lowered by the latter in trains of 4 waggons (10 tons net); but at the cage-drop their contents are transferred to small tubs, holding 1·65 ton, which pass down one at a time.

Shipping Pier.—The coast at Salta-Caballo being (like that at Poveña) exposed to the heavy gales and seas from the Atlantic, the pier is designed to fulfil the same conditions, and the final plan adopted is shown in the accompanying photograph. It consists of a steel trapezoidal truss, braced vertically and diagonally, 69 metres length over all, supported at the centre and landward extremity, and projecting at the seaward end. The leading dimensions are given in the diagram (Plate XXXVI. fig. 2), and the photograph (Plate XXXIV.) shows the pier and the foot of the cliff down which the cage-drop is built. The total weight of iron-work is 174 tons.

The superstructure of this pier was designed and manufactured by M. Auguste Lecocq of Halle, Belgium, from data supplied by the Setares Company, and has since been reproduced at several places in Spain, both in this province and in the south.

The method of shipping is by small tubs, carrying $1\frac{1}{8}$ ton, direct from the drop already described and simultaneously from the ore stock, which is built with five compartments, under each of which the tubs come, and are loaded through a door.

On the pier three roads are laid of 2 feet gauge, converging into two at the end over the spout. In this way 2158 tons have been loaded in 7 hours, and 3000 could be dealt with in

12 hours without great effort. During 1895 the shipments at this pier were 250,463 tons (English), and the total shipped from the commencement of operations in January 1888 is 1,412,736 tons.

The works described were carried out under the direction of Don Juan M. Alonso Allende, mining engineer, Bilbao.

Dicido.

This group is adjacent to that of Setares, and, lying on the western slope of the same range of hills, it finds its natural outlet in the little creek of Dicido between Salta-Caballo and Castro-Urdiales.

The principal mine is the "Anita," which has been worked (intermittently) since 1873. For many years the ore was brought down to the shore by a Hodgson wire ropeway, and discharged into lighters for shipment.

In 1883 the ropeway was replaced by an endless chain, and the lighters were substituted in 1886 by an iron screw-pile pier. The mine has been worked regularly ever since, the average annual output being 150,000 tons.

The pier was washed away in the great gale of 30th December 1894, and has been replaced by a truss of almost similar design to that at Salta-Caballo, but longer, wider, and with two stories (like that at Poveña). This pier was built by J. L. Lecocq & Co., of Halle, Belgium, from the designs of Mr. T. Seyrig of Paris, the plans being revised by Sir Benjamin Baker, K.C.M.G., Past President of the Institution of Civil Engineers, and the total weight of ironwork in the superstructure is 300 tons. At the shore end it is anchored in a vaulted recess. As it only commenced working in March last, its capacity has not been fully tested; the present rate of shipping is 200 tons per hour.

The endless chain railway is 3000 metres (3280 yards) in length from the mine to the pier, with a total fall of 350 metres (1148 feet). The gauge is 0·046 metre (1 foot 5·7 inches) and the rails weigh 8 kilogrammes per metre (16 lbs. per yard); its operation is automatic. The thickness of the chain is, for 2500 metres, 26 millimetres (1·02 inches), and for 700 metres 18 millimetres (0·7 inch). The tubs carry each 540 kilogrammes (10·6 cwt.) of ore, and are spaced 15 to 25 metres ($16\frac{1}{2}$ to $27\frac{1}{3}$ yards) apart on

the chain. The maximum daily capacity of this chain railway is 1000 tons, the average present rate 500 tons, and the cost is 0·30 peseta (2½d.) per ton of ore brought down.

The pier is the property of the Dicido Pier Company, Limited, and the mines and chain railway of Messrs. J. B. Davies and Guillermo de Goitia of Bilbao; and all are worked under lease by the Dicido Iron Ore Company, Limited.

Plate No. XXXV., taken from a photograph, represents a view of the new pier, whose leading dimensions will be found on the diagram (Plate XXXVI. fig. 3).

Works in progress at Onton and Castro-Urdiales.

At Onton, between Poveña and Salta-Caballo, and to the eastward of the river-mouth, a new pier is being built, which, when completed, will be the largest of its class. Owing to the rocky nature of the bottom at this part of the coast, the pier will project no less than 65 metres (213 feet) seawards. The leading dimensions are given in the diagram (Plate XXXVI. fig. 1), from which it will be seen that the truss differs in form from those at Salta-Caballo and Dicido. The pier is being constructed and erected by the Sociedad Vasco-Belga of Miravalles, and the total weight of ironwork is 400 tons.

A railway 2⅜ kilometres (1½ miles) in length, of 0·75 metre gauge, is being built to connect it with the mines, which lie further to the eastward and adjoin those of Cobaron, already described. The mines are the property of Messrs. Chavarri Brothers of Bilbao, by whom they will be worked, and for whose account the railway and pier are being built.

At Castro-Urdiales, a seaport 1½ mile to the west of Dicido, important works are being carried out for the reception and shipment of minerals from the Sopuerta and Alen districts in the province of Biscay.

Two railways are now in progress, one of which terminates in the little harbour of Castro (where a pier similar to that of Dicido, but smaller, has been erected by the Sociedad Vasco-Belga), and the other in the neighbouring small bay of Urdiales (Plate XXXVI. figs. 4 and 5). These railways and piers when completed will withdraw a certain amount of mineral traffic from those of the Bilbao district.

SANTANDER.

The province of Santander, long celebrated for the value and extent of its deposits of zinc ore, has of recent years become known as an important source of iron ore supply. It is impossible, within the limits of the present paper, to do justice to the iron ore industry that is being developed in this province; but a few notes upon the mines now being worked in the neighbourhood of the port of Santander, coupled with the map (Plate XXXVII.) which has been specially prepared for this paper, may, when added to the description already given of those near the borders of Biscay, assist members in forming some idea of its growing importance. This importance is chiefly due to the attention given in recent years to the concentration by washing of the ore found in the Cabarga Mountain, and in the districts of Cabarceno and Solares, situated in the extensive valley to the south and south-east of it.

The Cabarga Mountain lies about three English miles south of the suburb of Astillero, on the bay of Santander. It runs nearly east and west, and the chief deposits of iron ore are at the western end of the range. Both in the mountain slopes, and in the extensive tract of country behind it, the iron ore is found in superficial deposits of ore clays and earths, containing lumps and nodules of ore of varying sizes, down to the finest sand, the bulk of it being, when washed, like gravel.

Some resemblance exists between these concretionary deposits and those of Ollargan, near Bilbao, and they may well have had the same origin: as beds of rounded and waterworn nodules are found alternating with others bearing no trace of wear. They lie upon the dolomite and limestone, and in intimate connection with them. The deposits vary in depth from a few feet to several yards, and in the valleys, between some spurs of the mountain at the western end, the depth has been proved by borings to 185 feet. The cross and longitudinal sections in which this occurred are appended (figs. 10 and 11).

The percentage of ore to clay, after washing, varies very much according to the district, but the better class of deposits may be taken to average 20 to 30 per cent. of ore. These deposits had been worked on a small scale many years ago, but not profitably.

The ore was screened, and carted down to the bay for shipment, but the quality was unsatisfactory and the cost very high.

Attention had been turned from time to time to rendering it marketable by washing. Messrs. W. Baird & Co. had for many years successfully applied this process to the small stuff found in some of their workings at Camargo (about three miles to the north-west of Cabarga), while others commenced to experiment in Cabarga itself. In 1889 the San Salvador Mining Company put down modern washing-plant for the mines leased by them in Cabarceno, and about the same time Mr. Joseph MacLennan commenced the important washing installation at Solia for his Obregon mines at the west end of Cabarga Mountain.

Other enterprises followed, chiefly supported by Bilbao capitalists and miners, and the following table gives the approximate output of ore washed in the year 1895:—

	Tons.
J. MacLennan, Obregon	65,000 estimated.
S. Salvador Mining Company, Cabarceno	35,000 ,,
William Baird & Company, Limited, Camargo	30,000 ,,
Picavea & Company, Solares	15,000 ,,
Chavarri & Company, Puente Arce	13,000 ,,
Mata Zamacona & Company	3,000 ,,

In 1896 two additional firms commenced operation, viz.:—

Heracleo Soto & Company	Resguardo Mine	Cabarga.
C. San Gines & Company	Ciega Mine	

Quality of the Washed Ore.

The Cabarga and Cabarceno ore when washed gives about 56 to 59 per cent. of metallic iron, according to the grade of washing. In other parts of the district the ore appears to be leaner in places.

The following analysis is that of a cargo of Obregon ore shipped in June 1895 to the Dowlais Company, per s.s. *Jane*:—

	Dry.	Moist.
Iron	58·80	55·59
Residue	3·90	3·68
Sulphur	0·073	0·069
Phosphorus	0·028	0·026
Lime	0·50	0·47
Manganese	0·33	0·31
Magnesia	trace	trace

This is richer in metallic iron than Bilbao ore, but higher in phosphorus and sulphur.

The Obregon group of mines, owned in part by the Vizcaya Santander Mining Company, Limited, and in part by Mr. Joseph MacLennan, by whom they are worked, consists of the mines and demasias known as "Deseadas" and "Chitones" (and others), covering an area of 750 acres. They are situated at the western end of Cabarga Mountain, and the ore clays are formed both in the valley and up the slopes on the northern face, and on the ridge top, and a portion of the southern and western slopes. The extent of mineral ground as ascertained by borings is about 300 acres.

The portion at present worked lies on the northern slope. The workings consist of a series of terraces connected by zig-zags with one another, and with the terminus of the railway leading to the washers and shipping place. The working faces are from 6 to 8 metres in height (19 feet to 26 feet) on an average, and the clay is loaded into the railway waggons at the face itself; no selection is made, but everything is loaded up and sent to the washers.

The noses and pillars of dolomite found are not blasted away, but the workings are carried round them as far as possible by means of barrow roads, when it is not possible to slue the lines of rails to suit them. The photograph (Plate XXXIX.) gives a general view of the workings, and shows clearly the dolomite pillars where the clay has been excavated.

The average daily quantity of clay dug, filled, and sent to the washers amounts to about 1500 tons. The average weight of one cubic metre of ore and clay is from 2 to 2·3 tons, when cut from the solid, and 1·3 ton measured loose in the waggon. The waggons are formed into trains of 33, and are hauled by a locomotive to the washing station at Solia, a distance of 2¾ miles, the gradient falling at the average rate of 1 in 50. The waggons are end-tipping, and each contains 2 cubic metres of loose stuff. The train load of 33, therefore, contains 66 metres or 86 tons.

Washing Plant.—The clays brought from the mines are discharged over a high gantry behind the washing machinery; here they are played upon by water delivered under strong pressure through 3-inch hose-pipes; this causes a preliminary segregation of the ore lumps and clay, which slide down sloping surfaces to

the trommels, leaving the heavier lumps behind on a grating, whence they are removed in small waggons to the stock heaps. The washing machinery consists of six trommels revolving on friction rollers; they are 21 feet 3 inches long over all, by 7 feet 2 inches diameter (see photographic view, Plate XXXIX.). In these, the earth is separated from the ore by means of internal lifting plates, combined with a spiral rib, which cause the ore to be continually carried forward under a copious stream of water. The delivery end of the trommel is conically formed to facilitate delivery, and to keep the dirty water from flowing out at that end.

The ore gradually passes along the trommel and drops into waggons underneath, and the earth escapes from the back of the trommel suspended in water, which carries it away in wooden conduits to a large settling ground in the Solia marsh (Plate XLI.), whence the water eventually flows back to the river in a clean state, so that no nuisance is created.

There is a supplementary arrangement of spitz kasten, acted on by inverted jets of water to catch the fine ore-sand that escapes in the mud; but these are only partially successful, and nearly 30 per cent. of this fine stuff still passes away to the marsh. As far as possible, it is made to settle at a point near the washers, whence it is loaded into waggons and again taken up to the trommels to be re-washed. In this way only 5 per cent. is eventually lost, but some better arrangement to save the "fines" at the first operation, and avoid re-washing, is now being studied. The water for the trommels is raised from the river by three 8-inch centrifugal pumps, while a fourth pumps water for cleansing the "fines" after they leave the trommels.

The whole of the plant is driven by a compound horizontal engine of 260 horse-power, capable of driving four additional trommels (Plate XL.). Steam is supplied by two cylindrical boilers 29 feet 6 inches long by 7 feet 2 inches diameter, with corrugated flues. The machinery was supplied by the Humboldt Company of Cologne. The other ironwork was supplied by Lavine & Co. of Astillero.

The present daily average quantity of washed ore turned out in ten hours is 306 tons, but the machinery is capable of washing 400 tons, if sufficient clay could be brought down. The clay

at present being washed gives about 21 per cent. of washed ore, exclusive of 40 tons of "fines," that at present escape daily.

In connection with these washing operations, the importance of ample deposit and settling ground for the mud is evident. Fortunately the bay of Santander affords extensive tracts of tidal marsh suitable for this purpose, and capable of being reclaimed by embankments of easy construction. The ore, after coming from the washers, is tipped to stock, ready for loading into railway waggons for transport to Astillero and shipment.

Railways.—The railway is a single line throughout (of 1 metre gauge), with passing places.

It is in two sections, viz.:—

	Kilometres.
No. 1. From the mines to the washing station at Solia	4·090
No. 2. From Solia to the shipping place at Astillero	4·948
Giving as total length of main line	9·038
To this must be added sidings and zig-zags in mines, amounting to	7·268
So that in all the length is	16·306

On the second section the line runs alongside the tidal river of Solia, and the slopes of the embankments are pitched with stone.

At 3 kilometres from Solia, there are receiving stations for Mine Ciega (C. San Gines & Co.), Mine Resguardo (H. Soto & Co.), and near Astillero another is being put down for Mine Concha (Zamacona & Co.).

The ore from these various mines is, or will be, carried by this railway, and shipped at Astillero; and other important groups are expected to be connected with it for the same purpose. At Solia are repairing shops, engine and waggon sheds, stores and dwelling houses.

The gradients are:—Section No. 1, 1 in 50 down to Solia, then level to Gantry; Section No. 2, level till within a short distance of Astillero, then a rise of 1 in 110 on to shipping pier, to gain height. The zig-zags at the mines are laid to gradients of 1 in 30.

Shipping Place.—At Astillero are the chief offices and shipping station and pier, the latter on the bay of Santander. The shipping pier is a substantial iron structure (Plate XLII.), composed of wrought iron hollow piles, driven down into the rock,

with a superstructure of plate girders on which the rails for full and empty lines are laid. The platform is decked with 3-inch planking; the pier-head is T-shaped, with room for discharging cranes for coal and material. The whole of the ironwork was supplied by the Horsehay Company, of Horsehay, R.S.O., Salop. The loading spout is of the ordinary inclined pattern. The bay in front of the pier is wide, and steamers can swing easily. The height of platform above ordinary high-water is 9 metres (29 feet 1 inch), and the depth of water at low spring-tides is 15 feet.

The shipping capacity of the pier is 2000 tons per day; but as a rule about half that quantity is loaded. An agreement has recently been entered into for the purchase of the mining works, railway, and appliances described, and for a lease for ninety-nine years of the Obregon mines by the Orconera Iron Ore Company.

The group of mines worked by the *San Salvador Spanish Iron Ore Company, Limited*, is situated in the district of Cabarceno, to the south of the Cabarga Mountain. It is unfavourably placed as to water for washing purposes, the clays having to be brought over the mountain to the hamlet of San Salvador on the right bank of the tidal river that enters the bay at this place.

The haulage is effected by an endless chain railway 3½ kilometres (2¼ miles) length, 1 foot 6 inches gauge. The tubs hold about 12 cwt. of ore-clay, and the average quantity brought down per day is from 500 to 600 tons. The clays undergo a preliminary selection in the quarries, so as to keep the quality sent to the washers at an average, which appears to be from 25 to 30 per cent.

The washing machinery consists of four trommels 15 feet in length by 6 feet 6 inches in diameter. The clays are tipped into the trommels through hoppers, without being first played upon by water through hose-pipes as at Solia; but in other respects the washing process is very similar to that described already. The mud runs away to embanked marsh ground reclaimed from the river. The washed ore is transported, partly by a tramway, partly by cart, to a stock heap at the shipping pier at San Salvador, a timber jetty with iron spout of the usual pattern.

The quantity of washed ore shipped by this company in 1895 (with three trommels) was 35,336 tons, giving about 120 tons as the average of a day's washing. In the present year a fourth trommel has been added, and a correspondingly larger output may be expected. Full particulars of the chain railway and washing plant will be found in a paper written by Mr. F. Kensington, and published in vol. cxvi. of the *Minutes of Proceedings of the Institution of Civil Engineers.*

The Camargo group of mines, worked by Messrs. William Baird & Co. for many years past, is situated to the west of the bay of Santander, and about 10 kilometres from the town. The principal mines are the Carmelina, Desengaño, La Francisca, and Nueva Trinidad.

In some notes upon the iron ore deposits of Santander, courteously furnished to the author by Don Arsenio de Ordriozola, Government Engineer of Mines, the latter says, speaking of Camargo: "In the lower parts of the ore-masses, rich pockets of iron pyrites are often found, and this, when coupled with the fact that a certain quantity of pyrites is found mixed with the iron ore, might favour the supposition that the latter has been formed by the decomposition of the pyrites."

The bulk of the ore (Rubio, with 52 to 54 per cent. of metallic iron) is quarried in the usual way, but a certain proportion of small stuff is washed, after undergoing a preliminary selection and screening.

The washing-plant consists of a Patouillet longitudinal open trough, driven by a steam-engine of eight horse-power, in which the ore and clay are stirred by beaters; the washed stuff runs out into waggons, and is hauled away direct to the stock-heap. The water is pumped up from the valley below, and by an ingenious arrangement of settling tanks much of it is used over again. The settling pond for the mud is embanked in a hollow, and the level is gradually raised about 2 feet at a time, so as to create no sudden pressure on the bank; in fact the mud forms its own bank as it rises.

The ore is transported from the quarries and the washers by a railway 4 kilometres ($2\frac{1}{2}$ miles) in length, to a stocking gantry at the head of a short inclined plane leading down to a loading

platform alongside the Guarnizo station of the Northern Railway of Spain. It is here loaded into railway trucks, and taken to the quay at Santander, where it is shipped by hand. The total quantity of ore shipped from Camargo in 1895 was 75,667 tons, of which perhaps 16,000 would have been washed.

The smaller installations and mines in Cabarga, referred to on page 85, are connected with the Obregon and Astillero railway (before described) by wire ropeways of the Hodgson type. The ore is washed in Patouillet troughs of a later pattern than that of Camargo, with a short revolving trommel placed at the delivery end, to improve the cleansing process. This type of washer has the advantage of cheapness, both in first cost and in operation; but in its present form it does not turn out the ore so cleanly washed as by the trommels, and it seems to produce a larger proportion of clay "balls" than these.

Plate No. XLIII. gives a photographic view of one of the latest washing stations built of this pattern; it is that of the "Ciega" mine, and consists of two Patouillet troughs, turning out daily about 130 tons of washed ore, giving an average of 56 to 57 per cent. of metallic iron.

At *Solares*, near the railway station of the Bilbao and Santander Railway, is a washing station somewhat similar to that of the "Ciega," but of older pattern; the ore is transported by the railway to Santander (11 miles) and shipped by hand at the quay.

At *Hoznayo*, 3 kilometres to the east of Solares, there is another small washing plant; the washed ore is carted to Solares station for transport and shipment at Santander. Efforts are being made to start other groups of mines in the Cabarga and Hoznayo districts, but the want of water for washing, and of convenient railway carriage, has hitherto been a drawback.

General.

A scheme exists for building a railway about 13 miles in length, along the south side of Cabarga Mountain, through the villages of Pámanes and Solares, to a point on the bay of Santander, immediately opposite the Astillero shipping pier. Were this built, no doubt it would serve to open out several promising

groups of mines, but there are difficulties in the way of water for washing, and settling ground for the mud.

The quantity of iron ore shipped at the port of Santander, or at the shipping places on the bay, during the year 1895 was 203,442 tons, of which 149,500 tons went to British ports, and 51,600 tons to Germany: adding to this the shipments from Setares and Dicido, the total iron ore now exported from the province of Santander reaches an approximate total of 600,000 tons annually.

The output for 1896 will certainly exceed these figures, and the increase will continue, though the rather optimistic expectations entertained by many who are interested in the mining industry of the province may not be all realised. The expense of transporting such large quantities of clay in proportion to the amount of washed ore shipped, and the increasing difficulty, as time goes on, of providing room for the mud, will always be drawbacks to working on a large scale. Nevertheless the ore grows in favour with buyers as it becomes better known; and Santander will, in the development of its iron ore deposits, regain the importance it formerly possessed as a mining centre, before the decadence of its zinc ore industry.

Reocin.

Any description of the province of Santander would be incomplete without some reference, however brief, to the Calamine and Blende Mines, and the appliances for their preparation, of the *Real Compañia Asturiana de Minas*, at Reocin, near Torrelavega, about 18 miles from Santander, on the railway to Madrid. For a detailed description, members are referred to an article by Don Arsenio de Ordriozola in the volume for 1889–90 of the *Estadistica Minera de España*, pp. 176–184.

The mining concessions cover an area of 515 hectares (about 1150 acres) and the workings extend for a length of 3 kilometres, (2 miles) by 120 metres (131 yards) in width; the ore-mass being proved to a depth of 110 metres (360 feet). The workings are open-cast, and present a picturesque appearance from the huge pillars of dolomite left standing in all directions.

The dressing machinery is elaborate and efficient, and com-

prises crushing, washing, and jigging plant, and two very interesting Linkenbach tables, 33 feet in diameter, for treating the slimes, and which separate with great nicety the calamine, blende, galena, and refuse at one operation. There are twenty kilns of various classes for roasting the calamine after it is dressed.

Much of the calaminiferous earth is associated with iron oxide, and the latter is separated in electro-magnetic apparatus, after being rendered magnetic by calcination. When ready for shipment, the ore is transported by the Company's metre-gauge railway, 9 kilometres (5½ miles) in length, to its shipping pier at the mouth of the Suances River.

The Reocin Mines have been in operation since 1857, and for many years the annual quantity of zinc ore shipped was 30,000 tons, involving the getting, loading, and treatment of about 200,000 tons of earth, in addition to the removal of a nearly equal amount of overburden.

The present annual output is about 15,000 tons.

In conclusion, the author apologises for the length of this paper, due to the extent of the districts described, and to the variety and importance of the works and appliances claiming attention. At the same time he tenders his sincere thanks to all the numerous friends and colleagues who have furnished him with data regarding the works under their charge, or who have assisted him in the preparation and revision of the manuscript and illustrations.

APPENDIX A.

ANALYSES OF ORCONERA IRON ORE COMPANY'S ORES.

	Vena.	Campanil.	Rubio.	Spathic Ore. Grey.	Spathic Ore. White.	Spathic Ore. Calcined.
Ferrous oxide, FeO	...	...	...	51·064	53·240	2·402
Ferric oxide, Fe_2O_3	79·96	78·03	78·29	6·271	6·742	87·142
Alumina, Al_2O_3	1·44	0·21	1·15	0·180	0·090	0·100
Manganous oxide, Mn_2O_3	0·70	0·86	0·74	...	...	1·860
Protoxide, MnO	...	...	...	1·727	1·961	...
Lime, CaO	1·00	3·61	0·50	2·250	1·800	2·650
Magnesia, MgO	0·55	1·65	0·02	0·160	0·250	0·105
Silica, SiO_2	8·10	5·91	8·80	4·500	1·200	4·800
Sulphuric anhydride, SO_3	0·10	0·01	0·05	0·048	trace	0·645
Pyrites, FeS_2	...	..	...	1·831	1·317	0·000
Sulphur, S	0·05	trace	0·04	...	...	...
Phosphoric anhydride, P_2O_5	0·03	0·03	0·02	0·017	0·025	0·016
Carbonic anhydride, CO_2	...	5·00	...	32·000	33·500	0·285
Combined water, H_2O	8·25	4·60	10·55	...	...	...
Total	100·18	99·91	100·16	100·048	100·125	100·005
Metallic iron, Fe	55·97	54·62	54·80	43·70	45·73	62·85

Note.—The sulphur in samples of Vena and Rubio is higher than usual. The metallic iron in samples of spathic ore is rather favourable; the average of seven cargoes of calcined ore shipped this year being 59·53 per cent.

APPENDIX B.

TABLE OF SHOTS FIRED IN VARIOUS CLASSES OF ORE, WITH COST OF LABOUR AND EXPLOSIVES.

Mine.	Class of Ore.	Labour Employed.						Explosives Used.						Total Cost per Ton. Ptas.
		Shot, No.	Depth, Feet.	Men, No.	Time, Days.	Wages, Ptas.	Cost per Ft. Ptas.	In Chambering. Kilos.	Charge for Shot. Kilos.	Total Kilos.	Cost, Ptas.	Tons brought Down.	Cost per Ton. Ptas.	
Orconera II.	Rubio	1	9	4	1¾	5·85	0·65	5·00	30·00	35·00	59·50	250	0·24	0·26
,, ...	,,	2	18	4	3¼	10·80	0·60	7·00	73·00	80·00	136·00	500	0·27	0·29
Orconera V.	,,	3	18	3	3½	12·60	0·70	10·00	52·00	62·00	105·40	320	0·33	0·37
,, ...	,,	4	14	3	3	9·80	0·70	7·00	27·00	34·00	57·80	200	0·29	0·34
Concha	Spathic	5	14	3	1	12·00	0·83	10·00	32·50	42·50	72·25	200	0·36	0·42
,, ...	Rubio	6	13	3	1½ & 2 hrs.	8·40	0·65	5·20	27·50	32·70	55·60	100	0·56	0·64
,, ...	,,	7	18	3	½	6·00	0·33	3·27	40·00	43·27	73·56	350	0·21	0·23
,, ...	,,	8	10	3	½	6·00	0·60	3·36	12·64	16·00	27·20	100	0·27	0·33
Cesar	Campanil	9	10	3	½	6·00	0·60	2·00	25·00	27·00	45·90	150	0·30	0·35
,, ...	,,	10	20	3	1¼	15·00	0·75	5·00	60·00	65·00	111·50	400	0·27	0·31
,, ...	Limestone	11	10	3	1	12·00	1·20	5·00	25·00	30·00	51·00	100	0·51	0·63

APPENDIX C.

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APPEN-

EXPORT OF IRON ORE FROM

Country.	1882.	1883.	1884.	1885.	1886.	1887.	1888.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
British Isles . . .	2,450,621	2,314,960	1,990,993	2,050,185	2,151,137	2,855,667	2,481,335
Holland	703,213	546,666	601,414	653,919	534,687	707,394	644,235
Germany	...	...	...	...	1,341	...	...
Belgium	73,408	49,767	102,541	93,489	98,442	98,304	103,602
France	450,436	459,119	455,596	491,085	332,103	356,980	347,687
Italy	...	...	...	...	...	...	...
United States . .	14,954	6,246	2,259	7,304	42,337	152,077	14,778
Other Countries . .	...	1,476	2,629	...	...	...	...
Coastwise	...	...	...	...	...	...	...
Totals . .	3,692,632	3,378,234	3,155,432	3,295,982	3,160,047	4,170,422	3,591,637

APPROXIMATE OUTPUT OF IRON

Approximate Output to 1881, Tons.							
11,844,819	3,855,000	3,627,782	3,216,321	3,311,419	3,300,667	4,400,000	3,960,000

APPROXIMATE CONSUMPTION OF

Approximate Consumption to 1881, Tons.							
386,495	120,112	198,069	177,130	242,945	296,885	379,880	430,110

DIX D.

BILBAO RIVER, 1882 TO 1895.

1889.	1890.	1891.	1892.	1893.	1894.	1895.	Total.
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	
2,770,125	3,040,562	2,245,613	2,609,000	2,952,000	3,024,000	3,122,000	...
640,261	647,980	631,765	754,000	560,000	691,000	600,000	...
...	...	...	...	...	...	...	...
93,010	106,525	66,316	74,000	106,000	82,000	148,000	..
378,347	388,516	342,163	384,000	325,000	324,000	288,000	...
121	...	...	...	...	...	...	...
3,748	89,335	30,607	34,000	10,000	1,000	16,000	...
...	...	...	...	...	...	4,000	...
...	...	...	...	...	30,000	36,000	...
3,885,612	4,272,918	3,316,464	3,855,000	3,953,000	4,152,000	4,214,000	52,193,380

ORE IN THE BILBAO DISTRICT.

4,180,000	4,740,000	3,840,000	4,210,500	4,360,000	4,566,000	4,572,000	67,984,508

IRON ORE IN BILBAO IRON WORKS.

442,130	502,350	472,625	405,000	456,000	463,000	407,000	5,379,758

LIST OF PHOTOGRAPHS ILLUSTRATING MR. GILL'S PAPER.

DISCUSSION.

Mr. Gill said that his paper was already so long that he did not wish to trespass on the time of the members. He would only say that, although so long, it did not by any means do full justice to all the interesting works and features of the Bilbao iron ore district. Special attention had been given to such works and installations as the members would probably visit. To those interested in the geological part of the paper, he might say that the engineer in chief of the province, Don Ramon Adan de Yarza, and all the engineers of the Government Department of Mines, placed themselves unreservedly at the disposition of the members in showing them all the interesting features of the place.

It had been found impossible to include in the visit to be made by the members all the mines of the province or district. Having in view the shortness of the time, the convenience of the members, and the desirability of avoiding unnecessary fatigue, certain works had been chosen which were fully explained in the programme. The members would see the principal mines, and the means of mechanical haulage adopted, which, after all, were the most interesting features of the district. In regard to the quarries, there was nothing particular to see, except the immense masses of mineral dealt with. The rendezvous chosen was one from which, without fatigue, the members could see a large number of installations, railways, inclines, and aerial ropeways. He hoped, therefore, that the excursion would prove an interesting one. He thanked the Institute for the honour of having been selected to prepare a paper for the meeting.

Dr. S. Rideal said the author had referred to three taxes levied upon iron ore by the Spanish Government, and had indirectly alluded to a possible further tax, which was at present under discussion. Perhaps he could give some further information as to the additional tax, which, it was understood, would be much higher than any at present levied.

Mr. Bauerman asked whether any crystallised hæmatite, specular ore, or any anhydrous ore had been found in the district? The soft red ore that he had seen seemed to be invariably one containing about 5 per cent. of combined water. Was there any obtained not containing combined water—actual hæmatite?

Mr. Gill said it was really the spathic ore transformed.

Mr. Bauerman said he had never seen any real hæmatite or crystalline ore in the district.

Mr. Gill said it could be found farther up in the next province. With regard to the additional tax (which had now been passed), it was 20 centimos (2d.) per ton. It was a tax on navigation, to be paid by the ship, not by the miner. In the case of Seville and the Mediterranean sea-board, the tax was 10 centimos, a difference being made in their favour.

Mr. G. J. Snelus, Vice-President, said that, in connection with the composition of the ores with regard to water, he wished to ask Mr. Gill if it had been exactly determined what was the difference in composition between the Campanil and the Rubio ore? When at Dowlais many years ago he looked into the subject, and, as far as he could make out, the one ore contained 10 per cent. of combined water, and the other only 5 per cent. It was a long time since he had had anything to do with the matter, and probably better information was now at hand as to which Mr. Gill could enlighten them. He believed he had found a constant 10 per cent. in the Campanil and 5 per cent. in the Rubio ore; but he was not sure whether the figures were not reversed.

Mr. Gill said the reverse was the case.

The President proposed a vote of thanks to Mr. Gill for his extremely instructive paper, and said he hoped the members would make themselves thoroughly acquainted with it before visiting the works.

The vote of thanks having been carried by acclamation, the

President said the next paper was by Mr. Snelus on "Further Experience with the Walrand-Legénisel Process." Two years ago Mr. Snelus contributed a paper on the working, on a small scale, of the Bessemer process by Walrand, which had attracted a good deal of attention. The present paper contained a description of the excellent results recently obtained.

The following paper was then read:—

FURTHER EXPERIENCE WITH THE WALRAND-LEGÉNISEL PROCESS.

By GEORGE J. SNELUS, F.R.S., Vice-President.

Having been requested by the Council of the Iron and Steel Institute to supplement my paper on the Walrand-Legénisel process by any further information available, I have much pleasure in doing so to the best of my ability, but regret that the time at my disposal has not sufficed to make the paper as complete as I could have wished it to be.

The following firms have now adopted this process:—

			Tons.
Legénisel (Paris)	1	converter	0·350
	1	,,	0·600
Schneider & Co. (Le Creusot)	1	,,	0·600
Hagener Gussstahlwerke (Hagen) . . .	2		0·600
Maquinista Guipuzcoa (Spain)	1	,,	0·350
Société Franco-Russe (St. Petersburg) . .	1	,,	0·350
Zimmermann & Co. (Halle am Saale) . . .	1	,,	0·350
Chantiers Baltiques (St. Petersburg) . .	2	,,	0·800
A. Baird & Son (Hamilton, Glasgow) . .	1	,,	1·000
Potter & Hollis (Chicago)	1	,,	0·500
Fraser & Chalmers, Limited (Erith) . .	Not yet settled.		

A considerable number of installations in this country and on the Continent are in negotiation. A small experimental plant was run for some time in Glasgow, for the purpose of making steel to cast direct into iron moulds for horse-shoes. Although the converter in this case only held about four cwt. charges, no difficulty was found in working the process, but naturally a larger percentage of ferro-silicon was needed to get the necessary fluidity from the afterblow. As showing the adaptability of the process to varying circumstances, I may mention that on one occasion, in order to see what the effect would be of using a very large excess of ferro-silicon for the afterblow, I added about 15 per cent. of ferro-silicon, containing 15 per cent. silicon, thus adding 2·2 per

cent. to the silicon in the blown metal. The details of this blow were as follows:—

Time. h.	m.	
4	4	Metal in converter turned up.
4	5	Pressure of blast 32 lbs. per square inch.
4	10	Appearance of sodium line in spectrum.
4	15½	Appearance of first green line in spectrum.
4	22	Ordinary blow finished, vessel turned down.
4	23½	15 per cent. ferro-silicon added in molten state, and vessel turned up for afterblow.
4	28	Vessel turned down and casting began by teeming successive portions from converter into crucibles for pouring.
4	54	Last metal poured from converter; still perfectly fluid.

It will thus be seen that in this case the afterblow lasted four and a half minutes. The steel was excessively fluid, and so soft that the cold metal could be bent nearly double without breaking. The blow was all that could be desired, and the spectrum of the afterblow was the most brilliant I have ever seen. Although the last portion was poured twenty-six minutes after the blow of only 4 cwt. was finished, it was sufficiently fluid, after this long period, to make good sand-castings. I much regret that, owing to a misunderstanding, no analysis of this particular cast was made; but it was undoubtedly very soft steel, and ran solid in the moulds. As showing that there is no difficulty in getting a large output from these small plants, I may mention that on one of my visits to Messrs. Legénisel's works, on a Saturday afternoon, my son and I saw them make seven consecutive blows from the 0·350 ton converter without the slightest hitch. On a previous occasion, I saw them start after 4 P.M., and get six blows all blown and cast by 8.44 P.M., the men employed for the whole of the work—charging cupola, blowing, teeming into moulds, &c.—being one foreman and eight hands.

Subsequent experience has in no way altered the favourable impression I expressed in my previous paper. The statement then made that the waste in the cupola was about 5 per cent. (about the ordinary figure) and in the converter from 10 to 12 per cent. is corroborated. No special mixtures of iron are needed, provided they are of Bessemer quality, and the mixture contains from 2 to 3 per cent. silicon and 0 to 1 per cent. manganese. All classes of steel can be made by the process by varying the additions after the afterblow.

Mr. Walrand classifies the varieties as under:—

	Silicon.	Manganese.	Carbon.
Special soft steel	traces	0·08–0·25	0·08–0·12
Soft steel	0·05	0·4–0·5	0·12–0·2
Ordinary steel	0·08	0·6–0·7	0·25–0·45
Hard steel	0·12	0·6–0·8	0·45–0·8

He also gives the following table of mechanical tests of special steels:—

	Tensile Strength. Tons per Square Inch.	Elongation.
		Per Cent.
Magnet steel (without manganese)	25–28	15–20
Steel for ordinary castings	28–35	12–22
Semi-hard steel	38–44	10–15
Hard steel	44–50	8–12
Special steel	28–32	20–35

These last steels are made by special means, which Mr. Walrand does not care to disclose publicly. The metal produced in the ordinary way is not only suitable for castings, but has been used freely for tin plates, wire billets, forgings, and tool steel. Negotiations are now in progress for applying this process on the large scale in ordinary Bessemer converters for all kinds of steel. Mr. Walrand has used it successfully in France, with 8-ton converters, and made exceedingly soft steel containing—silicon, traces to 0·03 per cent.; manganese, 0·08 to 0·3 per cent.; carbon, 0·08 to 0·12 per cent.

The following particulars are also furnished by Mr. Walrand:—

	Per Cent.
Consumption of ferro-silicon (10 per cent.)	5–7
,, ferro-manganese (80 per cent.)	1·5
,, aluminium	0·1
,, coke for cupola	10–12
,, coal for steam purposes	25

Amount of scrap from runners and heads, &c., of castings 25 per cent. of total steel, but variable atmospheres.

Pressure of blast, first period of blow	1·2–1·5 per sq. in.
,, second ,,	0·6–1·0 ,,
,, afterblow	1·0

Consumption of air per minute per ton of metal, about 30 cubic metres.

Number of blows per bottom, 10–12.

Number and size of tuyere holes, 6 tuyeres with 7 holes in each, 4 mm. diameter. Thickness of bottom, 30–35 cm.

Duration of converter lining, 400–500 charges.

All the scrap made in the process can readily be remelted with pig iron for the cupola charge. Indeed the process lends itself so well to the utilisation of scrap that Mr. Walrand has succeeded in making good castings, using 70 per cent. steel scrap in the cupola charge. So that not only can all scrap made in the process be used up, but where cheap scrap steel can be bought, an extra quantity may be employed with economy.

Some interesting particulars of the working of the process by Messrs. Potter and Hollis at Chicago, and by Mr. Sergius Kern at St. Petersburg, were abstracted in the last volume of the Journal of the Institute, No. I. 1896, pp. 451–454. I have been in communication with these gentlemen, and they all speak highly of the process, the latter remarking that "We think the Walrand Small Bessemer more suitable than the Robert or Tropenas."

The process is eminently adapted to the manufacture of special steels for various reasons: 1st. These are generally required in moderate quantities, and it is not possible to use the open-hearth or ordinary Bessemer process on account of the cost of dealing with such large quantities. 2nd. The metal bath at the end of the afterblow is so hot that any additions can be made safely and with ease, so that by varying these the nature of the steel can be varied with facility and with the minimum of cost. 3rd. If necessary, practically the whole of the silicon added for the afterblow can be removed, so that the bath will consist essentially of metallic iron and carbon, and thus the effect of varied additions, as for instance chromium, tungsten, titanium, &c., will be fully noted.

The mode of conducting the operations at the final stage are somewhat varied from those set forth in my original paper. Instead of continuing the blow until the spectrum is quite clear before turning the vessel down, Mr. Walrand finds it safer to turn down when the green lines of the spectrum begin to disappear, then to add the ferro-silicon and make the afterblow. By this plan some carbon is left in the bath at the first turn down, and a vivid spectrum is obtained for the afterblow. The final point for turning down can then be determined with greater accuracy by the spectroscope. As showing the composition of the bath at the first turn down by this treatment, my son, George J. Snelus, jun., when working at Messrs. Bairds',

Hamilton, found the metal bath at this point to contain carbon 1·3 and silicon 0·095.

After making the final additions Mr. Walrand prefers to put the blast on and turn the vessel up for an instant, to thoroughly mix the additions, but Mr. Sergius Kern thinks it better not to do this, and I am inclined to agree with him, as it is marvellous how soon the bath takes up oxygen when air is blown through it for an instant. If the additions are fluid and got well into the bath they will get well mixed in pouring. But it might probably be better to stir the bath with a dry pole before pouring. I prefer to finish the afterblow as soon as the first batch of green lines in the spectrum disappear.

The following analysis, supplied by the courtesy of Mr. Paul of the Steel Company of Scotland, shows the composition of pig iron used and steel made at Hamilton by George J. Snelus, junior:—

	Pig Iron.	Steel.
Graphite	2·760	...
Combined carbon	0·640	0·440
Silicon	2·660	0·110
Sulphur	0·055	0·060
Phosphorus	0·038	0·039
Manganese	0·480	0·610
Aluminium	...	0·036
Iron by difference	93·367	98·705
Totals	100·000	100·000

It is very important to note that a considerable portion of the aluminium employed is found in metallic combination in the steel.

As an illustration of the facility with which the process lends itself to the formation of steels of special composition, I may mention that, being desirous of studying the effect of a high silicon in combination with high carbon and high manganese, I obtained a steel of the following composition:—

	Sample XV.	Check Sample XV. x.
Carbon, by combustion	0·980	0·980
Carbon, by colour-test	0·950	0· 95
Silicon	0·933	0·933
Sulphur	0·052	...
Phosphorus	0·060	...
Manganese	1·076	...
Iron direct	96·900	...
Aluminium	0·111	...

The mechanical tests of this sample of steel after annealing gave: Diameter, 0·745 square inch; area, 0·436 square inch; total breaking stress, 18·5 tons; breaking stress per square inch, 42·43 tons; elongation on 8 inches, 4·0 per cent.; contraction of area, 4·12 per cent.

I have the pleasure of placing a sample of this steel on the table. It was exceedingly fluid, and enabled the founders to cast successfully a very intricate casting which they had previously failed to make from crucible steel. The metal ran very solid and quietly, and in an iron ingot mould piped exactly like ordinary crucible steel, but the castings fed thoroughly from the head, which remained fluid a long time. Although so high in carbon, it was by no means brittle, as the fracture of the sample showed. It was also exceedingly sound. I am indebted to Mr. G. Ainsworth for the analyses and tests of this steel.

It should be pointed out that it is by no means necessary to have a large plant even when making heavy castings, as the metal is so fluid that it may be accumulated for a large casting, and thus for instance a 5-ton casting may be easily made from a pair of 1-ton converters working together. Among the refinements introduced in the working of the process is a continuous recording blast-pressure gauge, designed by Mr. R. M. Daelen, by which a diagrammatic record of the blowing is obtained for future reference. The facility with which these small converters can be started just when wanted, and the requisite quantity of steel blown at short notice, and the plant laid idle without serious costs, is a matter of the utmost consequence to the founder.

It is found that the hotter the steel the better it casts, and its fluidity renders it especially suitable for green sand castings, of which a great many are being made.

With regard to the most important question of cost, this will necessarily vary in different localities, but at present prices in this country, taking pig iron at 48s.; ferro-silicon, 65s.; ferro-manganese, £12; coke, 16s.; coal, 8s., the cost of fluid steel in the ladle should not exceed 80s. per ton after allowing interest on capital and depreciation. The simplicity of the apparatus and cheapness of the process renders it an admirable adjunct to the ordinary foundry. As the plant can be started and stopped at short notice, the founder is enabled to make his own steel castings cheaply and promptly, and of any desired degree of hardness.

DISCUSSION.

Mr. SNELUS (after giving an abstract of his paper) said it was most important not to pass any air through the bath of metal when the silicon had practically all disappeared, because then they began to burn the carbon again, and generated carbonic oxide gas, which it was very difficult to get rid of. He could not too strongly emphasise the necessity of turning the vessel down at the proper point, so as not to leave gas in the steel. The process afforded great facility for getting a bath of metal free of gas. That indeed was a most important feature of the process; but if the steel was spoiled by the blowing being carried too far, they might as well be without the after-blow. There was one point about the process which might be specially mentioned. It afforded great facility for obtaining any special kind of metal that might be desired. When the metal was blown down in the after-blow and the silicon was got rid of, they had a bath of metal practically free from everything except a moderate quantity of carbon. If they wanted to make any particular alloy, a great advantage was offered.

On one occasion he was anxious to make an alloy as fluid as possible, in order to run a very difficult casting, which had been run three times and unsuccessfully, even out of crucibles. He made a special cast, naturally using a good proportion of ferro-silicon, and also stopped very short in the blow. He exhibited a sample of the steel made, and an analysis of it was given in the paper. He had to thank Mr. Ainsworth for having the analysis made. In connection with that it might be interesting to point out the homogeneity of the steel. When he was in Scotland, directly the metal was made he had borings taken from an ingot. A few days ago he re-bored the same ingot at another point, and the borings of the two were sent to the chemist at Consett, who did not know that they were from the same steel. He analysed them, believing them to be two different kinds; but the result was that the silicon and carbon came out exactly alike to the third decimal point. That showed the accuracy to which chemical analysis could be carried, and it also showed the homo-

geneity of the piece of steel. That was a point wholly collateral to the Walrand process, but he thought it might be of interest to the members.

He held in his hand a piece of steel which had been annealed, planed on all four sides, and fractured at both ends, in order to show the soundness of the bar. A test-bar from the same steel gave a tensile strain of practically 44 tons to the inch; it was therefore a very hard steel in regard to tensile tests, but not as hard as one would expect from the amount of carbon in it, which was 0·86 per cent. He assumed that the silicon had considerable influence in altering the character of the metal; for the metal, although being of almost tool-steel hardness as far as carbon went, was very tough, as could be seen from the broken ingot: practically it was almost malleable.

There was one other point that might be mentioned, relating to the cost of the material. There was so little cost involved in the process, that practically the cost of metal made in a small converter was very little above the cost of metal in the large Bessemer converter. Taking as the present market price of the materials used, hæmatite iron 48s., ferro-silicon 65s. (at which price it could be bought in Scotland), ferro-manganese £12, coke 16s., coal 8s. per ton, the cost of fluid steel in the ladle did not exceed 80s. per ton after allowing for interest on capital and depreciation. So that the method certainly afforded the means to a founder or to steel-works of producing steel suitable for castings at a very small cost. But he believed that the process would become available, as he had mentioned in his previous paper, in larger operations; and as a matter of fact Mr. James Riley was very anxious to apply it to all his Bessemer work. Other firms were also negotiating with that object in view. There was no difficulty in carrying out the process on a large scale, for in France Mr. Walrand had made by it the softest steel in 8-ton converters.

Mr. J. E. Stead, member of Council, asked Mr. Snelus if he could give an analysis of the steel (which was not given in the paper), as many members were looking forward to it. The ingot from which the test-piece shown by Mr. Snelus was taken was about the same size as that used in making tool-steel in Sheffield, and

he thought that if crucible ingots of that size were examined, it would be found that they were very regular indeed. The larger the ingots, the greater the liability to segregation. Freedom from segregation might be, as Mr. Snelus had said, a point in favour of the system, but it did not necessarily follow that large ingots would be equal to the smaller ingots. In casting any hard steel from an ordinary Bessemer converter into ingots of the same size as used by Mr. Snelus, probably equal homogeneity would be found throughout the mass.

Mr. SNELUS said the piece of steel he had shown contained combined carbon 0·86 and silicon 0·93 ; manganese, 1·075 ; phosphorus, 0·06 ; sulphur, 0·052 ; and aluminium, 0·11. He might point out, with regard to aluminium, that in the Walrand steel aluminium was found as an alloy; and he believed that if aluminium was put into ordinary Bessemer steel, very little would be left as metal in the alloy ; most of it would be burned out by the oxygen contained in the steel ; it then slagged away, and was not left to bestow the beneficial effect which it was assumed to have in causing fluidity. It produced a considerable effect, but a good deal was lost in the ordinary process. The exact figures of the tensile test were 43·8 tons per square inch, with an elongation of 4·5 per cent. in 8 inches. The tensile tests were also made in duplicate, by different persons, and they agreed very closely.

Mr. STEAD said he would like to know the actual amount of aluminium added to the steel. He could fully bear out the statement in reference to the oxidation of the aluminium charged into the steel. He had occasion a short time ago to examine a series of ingots filled from a ladle to which aluminium had been added. The first ingot was slightly piped in the centre, and free from honeycombs ; the second was solid throughout, and free from honeycombs ; the third had some honeycombs running through the mass, and the fourth, fifth, and sixth ingots respectively were increasingly honeycombed, showing that aluminium in a ladle of steel was gradually dissipated on standing in the molten state. Whether oxidation took place from the surface or in the mass of steel, it was difficult to say. In the

past he had been of opinion, shared by most practical men, that a small converter was not the best kind of vessel to use in steel-making: the trouble and expense were very great, and the steel was very liable to get cold, and to cause a production of skulls. By the process described, the addition of a large amount of silicon resulted in greater heat, and this, together with the final addition of aluminium to the blown metal previous to casting, placed the small converter on a different footing from that which it occupied before. He considered that aluminium was more responsible than anything for getting good sound castings when it was added just before pouring.

Mr. SNELUS wished every one to understand that the steel in question had been made for a special purpose. Any quality could be made by the process, but he thought the alloy described was such an interesting one that it was worth while investigating it and recording the facts. There was one point that he had omitted in giving the substance of the paper, namely, the facility which the process gave for using up scrap. The scrap made in an ordinary steel-foundry would perhaps amount to about 25 per cent. of the whole weight of steel made, and it was important to be able to re-melt it with advantage. By this process it could all be used with advantage. Mr. Walrand had gone still further, and had melted no less than 70 per cent. of scrap in the cupola by special means, and had been able to make good, sound castings out of the product. As scrap could be bought cheap, it was obvious that the process could be used with great economy.

Mr. E. P. MARTIN, Vice-President, said that in using so large a proportion of steel in the cupola, a good deal of white metal was probably obtained. He should like to ask whether it did not contain a good deal of sulphur?

Mr. SNELUS said the sulphur would depend upon the materials (metal and coke) used. He believed the result was not a white metal, but a grey metal. It was a modification which Mr. Walrand had introduced into the process, and which he did not desire to make public. It was not patented, and he was

not at liberty to describe the process, but he knew that 70 per cent. scrap was used in the charge.

Mr. HARBORD said that as Mr. Snelus had referred to the possibility of making dead soft steel on a large scale, he should like to ask what was the waste in making that sort of steel as compared with ordinary Bessemer? His experience of small side-blown converters was that the waste was very excessive in making dead soft steel. He would also like to ask whether, if aluminium was added to dead soft steel, it would not become as much oxidised as if it were added to ordinary Bessemer steel? Was not the lack of oxidation rather due to the high carbon steel which Mr. Snelus had been making by the process?

Mr. SNELUS said it was obvious that the amount of waste in the process did not in any way depend upon the ultimate quality of the product, because that part of the process where the waste occurred was the same whatever steel was made. He wished to make it clear that the waste of the process took place in blowing the metal, to begin with, down to the ordinary point of turning down, and also in the waste of the ferro-silicon which was blown to get up the extra heat in the after-blow. Whatever the quality of the steel being made, those operations could always be carried on in the same way. The waste varied with the kind of iron used and the amount of ferro-silicon employed for the after-blow. Ordinarily, Mr. Walrand found that the waste was from 10 to 12 per cent.; but in using a very siliceous pig iron to begin with, no doubt the waste would be higher. But it was very little more in making soft steel than it was in making hard steel.

With regard to the oxidation of the aluminium, the carbon probably had an influence in preventing oxidation of aluminium, because the bath containing so much carbon was freer than usual from oxide of iron. He could understand that in the Robert process, and all processes where the blowing was from the surface or near the surface, the amount of oxide left in the bath was so great that the aluminium added to such charge was rapidly oxidised and lost, and was also lost in the same way,

but he thought not to the same extent, in the ordinary Bessemer process, and for the same reason.

The PRESIDENT proposed a hearty vote of thanks to Mr. Snelus for his contribution, which was carried by acclamation.

The following paper was then read:—

THE ROASTING OF IRON ORES, WITH THE VIEW TO THEIR MAGNETIC CONCENTRATION.

BY PROFESSOR H. WEDDING, BESSEMER GOLD-MEDALLIST.

LONG before iron ores were smelted for pig iron in the blast-furnace, roasting processes were employed prior to the direct extraction of the metal from the ore, and, after the introduction of the blast-furnace process, the roasting of iron ores was still retained. As a rule, the roasting is a preliminary to the reduction process. It is only exceptionally or incidentally that it has to effect the purpose of simultaneously eliminating elements, such as sulphur or arsenic, that could detrimentally influence the iron produced. It is only in very recent times that roasting processes have also been employed in order to render iron ores magnetic, so that they can subsequently, by magnetic concentration, be freed from gangue, that is, from constituents not containing iron, and be enriched in iron.

On considering the composition of the ferruginous constituents of the ores practically employed in the metallurgy of iron, there will be found, as a rule, in the ores supplied by nature, oxides, hydrates, and carbonates of iron: magnetic oxide in magnetite ores; ferric oxide in red hæmatite ores; ferric hydrate in brown hæmatite ores; ferrous carbonate in spathic iron ores, clay iron ores, and carboniferous iron ores. If sulphur compounds occur, which have to be used as iron ores, as, for example, iron bisulphide in iron pyrites, they must always be first converted into ferric oxide (purple ore) before the material can be further utilised in ironworks practice. Again, from the hydrates water must be expelled, and from the carbonates carbon dioxide, before the iron of these ores can be reduced.

The heats of combination of all iron ores show that a reduction to iron cannot occur as long as sulphur, water, and carbon dioxide are still present. It might consequently be assumed that the only object of roasting was the expulsion of sulphur, water, and carbon dioxide, with a view to the reduction of the iron, were it

not that the practical facts were in contradiction to this, in that they show that as a matter of fact even more iron ores that contain neither sulphur, water, nor carbon dioxide, but that consist only of magnetic oxide or ferric oxide, can with advantage be subjected to roasting. The object of this is either to facilitate the subsequent reduction by the formation of the most easily reducible oxygen compounds, or to facilitate the reduction by loosening the texture of the iron ores.

Influence of Roasting on the Reducibility of Iron Ores.

Before the question of the advisability of magnetic roasting can be gone into, it is first necessary to consider the question of roasting as a preliminary to reduction. It is known that the heat of combination of ferrous oxide, FeO, with a molecular weight of 72, is equal to 74·59 gramme-calories;* that of magnetic oxide, Fe_3O_4, with a molecular weight of 232, is 269; and that of ferric oxide, Fe_2O_3, with a molecular weight of 160, is 210·08 (according to Favre and Silbermann, Berthelot, and Thomsen). The heats of combination of the two compounds of ferric oxide with water, and of ferrous oxide with water, are as follows:—

Ferric hydrate, $2Fe+3O+3H_2O=191{\cdot}15$ calories.
Ferrous hydrate, $Fe+O+H_2O=68{\cdot}28$ calories.

At the same time, in the combination of Fe_2O_3 with $3H_2O$ 19·06 calories are lost, that is, for one atom of water 6·35 calories, and for one atom of iron 9·536 calories are lost, or in other words 170 calories for every kilogramme of iron. These figures prove that brown hæmatite must decompose in dry air at ordinary temperature and liberate water. The more, however, this happens, the greater becomes the affinity of the water and the less easily is it liberated. According to the researches of Muck and Tommasi, by remaining for a long time in a dry place, or even by heating in water of from only 35° to 40° C., a portion of the water of hydration may be expelled; at 90° to 95° C., moreover, the oxide can be prepared perfectly free from water. It follows from the figures mentioned that for the separation of

* See Wedding, *Handbuch der Eisenhüttenkunde*, 2nd edition, vol. i. pp. 904–928.

the water from the ferric oxide not only is there no need for heat to be employed, but even that the heat which is required for the expulsion of the water is lessened. For the decomposition of brown hæmatite there is required for each kilogramme of water—

	Kilogramme-Calories.
1. Conversion of the solid water into the fluid state of aggregation	76
2. Heating to 100° C.	100
3. Evaporation	536
Total	712

On the other hand there was obtained $\frac{6354}{18}=353$ kilogramme-calories, leaving the balance of heat consumed $=359$ calories.*

From this it may be seen that for the decomposition of hydrated oxide of iron into ferric oxide and water, so slight an amount of heat is required that a preliminary roasting is necessary only when the reduction has to be carried out directly, as in the "direct processes," in which the waste heat of the fuel cannot be utilised; whilst in the modern blast-furnace process the waste heat can be utilised, after the reduction of the iron oxides is completed by the gases rising through the charge. This perfectly suffices for expelling the water. A roasting of the brown hæmatites previous to the blast-furnace process is consequently quite superfluous for facilitating the reduction.

With carbonate of iron the case is quite different. Raw carbonate of iron was neither formerly employed for direct production of iron or steel, nor is it used at the present day in the blast-furnace, except in small quantities or in exceptional circumstances. The carbon dioxide is rather always first driven off. The reactions that take place during this expulsion of carbon dioxide are largely dependent upon the temperature. At a moderate temperature the following reaction takes place:—

$$6FeCO_3=Fe_6O_7+CO+5CO_2,$$

or according to other authorities—

$$17FeCO_3=5Fe_2O_3+7FeO+5CO+12CO_2.$$

According to the one or other of these views there are ob-

* Compare *Eisenhüttenkunde*, vol. i. p. 910.

tained different quantities of heat units, which are necessary for the decomposition. Berthelot found for $FeCO_3$ 10,000, Kosmann 13,596 kilogramme-calories. Naumann, under the reservation that the minerals used in his investigations were not pure, gives for spathic iron ore the atomic heat of 21·1. According to Regnault's researches it amounts to 22·4. As an average it may be assumed that the heat of formation of anhydrous carbonate of iron from ferrous oxide and carbon dioxide, as measured from the heat of formation of oxides of other earths and metals in combination with carbon dioxide, may amount to 30,000, or in other words, to 259 calories for one kilogramme. It must, however, be pointed out that this heat value is less than that of many other carbonates, for example, calcium carbonate. The same heat is required for the decomposition as for the formation. All such thermal decomposition processes differ according to whether the gaseous products of decomposition remain in the space in which the decomposition is effected or are drawn off from it. In any case it is possible, without any difficulty, to drive off the whole of the carbon dioxide from all iron carbonates before melting results. This is not the case with all carbonates, as, for example, with lead carbonate. It is remarkable, too, that, unlike other carbonates, for example, calcium and magnesium carbonate, this decomposition is not possible without a simultaneous partial change of the carbon dioxide. A not inappreciable portion of it is converted into carbon monoxide, and the atom of oxygen thus set free combines with the ferrous oxide to form a higher oxide. As for this decomposition, in whichever way it is effected, there are necessary in any case for the kilogramme of carbonate about 259 calories, for which, in the heat of the gases remaining after the reduction of the iron oxides, an adequate source cannot be found, it is right that the *iron carbonates should be roasted before they pass to reduction*, that is to say, before they are charged into the blast-furnace. In any case the heat required for driving off the carbon dioxide is produced and utilised more cheaply outside the blast-furnace. If, on the other hand, it is desired to carry out the roasting in the blast-furnace itself, which, as has been already pointed out, is occasionally done, there will result the drawback that the reduction of the iron ores will take place in zones considerably deeper than after a preliminary roasting,

and that consequently an increased consumption of fuel (coke) will be necessary.

If iron carbonate is decomposed in a glass tube without access of air, and the gaseous products drawn off in such a way that there is never an excess of pressure in the tube, the reaction that takes place is that previously given:—

$$6FeCO_3 = Fe_6O_7 + CO + 5CO_2.$$

Carbon dioxide is never obtained alone according to the equation

$$FeCO_3 = FeO + CO_2,$$

nor is the reaction

$$3FeCO_3 = Fe_3O_4 + CO + 2CO_2.$$

The case is different when atmospheric air is allowed to enter. By higher oxidation of the iron the reaction can then be as follows:—

$$2FeCO_3 + O = Fe_2O_3 + 2CO_2.*$$

Proceeding from the equation $6FeCO_3 = Fe_6O_7 + CO + 5CO_2$, there is obtained $6FeCO_3 + O = 2Fe_3O_4 + CO + 5CO_2$ or $6FeCO_3 + 2O = 3Fe_2O_3 + CO + 5CO_2$, or in other words, heat is gained with each higher step of oxidation.

Still, if it has been shown that by the roasting the carbon dioxide is driven off, and consequently the reducibility of the carbonate brought about, the further question arises, what kind of roasting of the carbonates—that is to say, whether simple decomposition or the roasting in an oxidising or reducing atmosphere—would be of the greater advantage for the subsequent reduction? and with this is connected the question whether by the roasting of oxide of iron, *red hæmatites* for instance, any advantage whatever is gained for this reducibility. Such an advantage exists as a matter of fact, otherwise red hæmatites would only then be roasted when this was intended either for increasing the porosity of the ore, or for the expulsion of sulphur.

This question was thoroughly investigated so far back as 1880 by Åkerman in connection with the roasting of Swedish iron ores.

* Never, however, as Gromier assumes, $3FeCO_3 + O = Fe_3O_4 + CO + 2CO_2$, because free oxygen must then remain in excess. The equation then would rather be $6FeCO_3 + O = 2Fe_3O_4 + CO + 5CO_2$. Compare *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1895, p. 376.

Åkerman deals in particular with assays which had been performed by Tholander. It was shown that there was a variation in the reducibility of the native magnetic iron ores, of the composition Fe_3O_4, which varied not inconsiderably according to the temperature to which the ore was subjected during the roasting process. This change is of such a nature that when the ore is heated at a low temperature with free access of oxygen, considerable advantages ensue as regards the fuel consumption in the blast-furnace. Åkerman concludes that the reducing by roasting of a non-carboniferous ore can never be of real advantage in the blast-furnace, and that it is at the most merely non-injurious where sintering does not result after the deoxidation, and the ore is not rendered more compact from this cause. The ore never, however, becomes more compact by a sintering action, if during the roasting it is so strongly heated, that despite the fact that the furnace atmosphere is maintained of an oxidising character, it is reduced to a lower stage of oxidation. In this way the reducibility even of an iron ore containing oxide can be diminished by roasting at a high temperature. The fact that oxide iron ores can be somewhat more readily reduced after a *slight* roasting than results if they are charged into the blast-furnace direct and entirely unroasted, follows naturally from the change in their physical condition. In the case of magnetites an oxidising roasting is always of advantage, even when these ores are heated until they are completely sintered, provided that their state of oxidation is maintained at that of the oxide, which, it is true, is only then the case if the rise in temperature is slowly and carefully effected, and if there is an adequate supply of air during this process.

The advantage that exists in an oxidising roasting of magnetites is especially shown in the case of those iron ores which are accompanied by so-called dark gangue-stuffs, that is to say, by silicates containing ferrous oxide. Åkerman holds that the influence exerted by the roasting on the reducibility of the ores is largely due to the tendency shown by them to decompose carbon monoxide, and to take up carbon from it. If, as has been shown by Sir Lowthian Bell, iron ore is reduced by carbon monoxide at temperatures below 400° C. (350° to 400° C.), carbon deposits in the ore, carbon dioxide being formed in

accordance with the reaction $2CO = C + CO_2$, this reaction naturally influences the reducibility of the ore, and the fuel consumption in the blast-furnace. The greater, therefore, the tendency of the ore to separate and absorb carbon from carbon monoxide, the more advantageous is roasting to the blast-furnace treatment, and in this direction, too, as Tholander's * investigations have shown, oxidising roasting at a low temperature has an important influence. Åkerman's observations are undoubtedly accurate, but the explanations given need further development, as is seen from the publications of Wiborgh,† and Kosmann.‡ The latter observes, justly, that Wiborgh contented himself with deducing the greater or lesser degree of reducibility from the greater or lesser degree of compactness of the ores. In some respects this may be right, for it has often been customary, for a very long time past, to roast ores for the sole reason of making them less compact. Ores which could not be broken down in the ordinary way before roasting, may subsequently often be very readily reduced in size, especially if they are cooled down in water while still hot, or allowed to lie exposed to the air after the termination of the roasting operation. In the case of some iron ores, indeed, considerable care must be taken when roasting, as otherwise a complete pulverisation of the ore may be the result. Still, as Kosmann justly observes, this behaviour possesses only a minor importance. The fact, he says, is that the changes in the heats of combination in the roasted ores constitute the true cause of the altered degree of reducibility. The different degrees of oxidation correspond to different heats of combination, and to these those temperatures run parallel at which a decomposition ensues, either into oxygen and metal or into oxygen and a lower oxide. Metallic iron and ferrous oxide change, as is well known, when slightly heated in contact with air, into ferric oxide; on the other hand, when strongly heated at the roasting temperature, one obtains not the ferric oxide but the magnetic oxide. Kosmann forgets, it is true, to draw attention to the difference which ensues from the oxidation on the one hand to Fe_6O_7, and on the other to the magnetic oxide Fe_6O_8. He gives indeed as an example, that if at a red heat

* *Vide* Åkerman, "The Roasting of Iron Ores."

† *Stahl und Eisen*, 1888, No. I.

‡ *Ibid.*, No. IX.; *Journal of the Iron and Steel Institute*, 1888, No. II. p. 232.

steam is passed through an iron tube, magnetic oxide is formed on the inner surface of the tube, and not the ferric oxide; that is to say, that the magnetic oxide must have a higher heat of formation than the ferric oxide; but it must be added that, besides the magnetic oxide, the lower oxide Fe_6O_7 also forms, and that this possesses a higher heat of combination than does the higher oxide Fe_6O_8. Ferric oxide is reduced, therefore, and at first sight one might say most unexpectedly, more readily by carbon monoxide or carbon than are the other oxides, and even at a temperature below the boiling point of mercury. The reduction by hydrogen, too, takes place very readily at a low temperature, and slowly at a high temperature, a fact which was known to Berzelius. One may, on the other hand, assume that, using a high temperature, ferric oxide would be first reduced to one of the two oxides Fe_6O_8 and Fe_6O_7, or to FeO, before it changed into iron.

Hydrogen and carbon monoxide certainly act differently in this reducing action. Hydrogen reduces ferric oxide to metallic iron through the various oxide stages, as is shown by the following reactions:—

$$Fe_6O_9+2H=Fe_6O_8+H_2O$$
$$Fe_6O_8+2H=Fe_6O_7+H_2O$$
$$Fe_6O_7+2H=Fe_6O_6+H_2O$$
$$Fe_6O_6+12H=6Fe+6H_2O$$

Carbon monoxide acts differently, since ferrous oxide and carbon dioxide decompose again with the oxides Fe_6O_7 and CO; in other words, two opposite kinds of chemical reactions would have to take place at the same time, which, of course, can never happen. The following reactions are rather the ones that occur:—

$$Fe_6O_9+CO=Fe_6O_8+CO_2$$
$$Fe_6O_8+CO=Fe_6O_7+CO_2$$
$$Fe_6O_7+7CO=6Fe+7CO_2$$

According to Kosmann, what happens in the blast-furnace is much as follows:* Red hæmatite or ferric oxide is reduced even in the uppermost zone by carbon monoxide. From $Fe_8O_6+O_6$, six oxygen molecules are separated and absorbed by the carbon monoxide. These oxygen molecules correspond in Fe_8O_6 to a balance of two bonds which are deleted. The remaining four bonds

* *Stahl und Eisen*, 1888, No. IX.

are, however, only able to correspond to four molecules of oxygen. Another two molecules of oxygen, consequently, are split off, and are liberated for the reduction by carbon monoxide. This quite corresponds, according to Kosmann, to Wiborgh's analyses, according to which in the reduced ore only the ferrous oxide exists. There remains in the residue Fe_8O_4 only the composition $4FeO + 4Fe$, that is to say, there exists in the ores reduced in this way 43·7 per cent. of metallic iron. We can further assume, adds Kosmann, that as soon as the six molecules of oxygen are separated from the compound $Fe_8O_6 + O_6$ by the first stage of the reducing action, the reducing action further proceeds to the molecular rearrangement of the remainder of the Fe_8O_6 in such a manner that the sesquioxide constitution approaches that of the protoxide. The separated six molecules of oxygen would then represent not two but three bonds which disappear in the remainder Fe_8O_6, in consequence of which not two but three molecules of oxygen remain for the further action of the carbon monoxide. The remainder would then only represent the formula Fe_8O_3, and have the composition $3FeO + 5Fe$, that is, it would contain 56·04 per cent. of metallic iron, the same percentage which Wiborgh found in his analysis. The Fe_3O_4 of magnetite behaves differently in the blast-furnace. Being very hard to reduce, the ore must sink to a considerable depth down the furnace shaft to reach the zone of higher temperature. From the compound $Fe_9O_6 + O_6$ the separated six molecules of oxygen are seized by carbon monoxide, and in the remainder, Fe_9O_6, as the ore approaches in character to protoxide, three bonds become free, so that this residue has the composition $6FeO + 3Fe$. At the high temperature, however, and as the ore is in a zone at which the carbon monoxide that had been burnt to carbon dioxide seeks to decompose again into CO, the liberated metallic iron has to endeavour to pass into the state of the heat-resisting magnetic oxide, and it combines gradually with one or two molecules of oxygen. If it takes up one molecule of oxygen, the remainder, $Fe_6O_6 + 3Fe$, assumes the composition $Fe_7O_7 + 2Fe$. In the absorption of two molecules of oxygen, the composition becomes $Fe_8O_8 + Fe$. In the first case the reduced ore to be reoxidised contains 18·18 per cent. of metallic iron, and in the other case 8·8 per cent., which again agrees satisfactorily with the results

of Wiborgh's investigations. Kosmann justly concludes that the degrees of roasting to which an ore is subjected is a guiding preliminary to its subsequent behaviour when under treatment in the blast-furnace.

The way in which the reduction of the ferric oxide and the magnetic oxide is effected in the blast-furnace may also be considered to be as follows: In the first place, with increasing temperature, the decomposition of carbon dioxide into carbon and carbon monoxide diminishes, the ferric oxide absorbing far more carbon in this way—which afterwards helps in its reduction—than does magnetic oxide; and, secondly, with increasing temperature the reducing power of carbon monoxide diminishes, the final reduction to iron being consequently rather due to solid carbon than to carbon monoxide.

Ferrous carbonate, too, yields residues of different compositions after being roasted at different temperatures. The higher this temperature, the greater is the loss of reducibility in the blast-furnace which the ores experience. To prepare an iron oxide for reduction in the blast-furnace, it is consequently by no means immaterial in what way, that is to say, at what temperature and in what kind of atmosphere, the roasting is effected. Rather must that kind of roasting be considered the most suitable for the reduction in which, owing to a low temperature and oxidising atmosphere, ferric oxide is formed from magnetite and spathic carbonate, or is retained in red and brown hæmatites.

This review of the reactions had first to be presented to show that every roasting by which a magnetic product, Fe_6O_8 or Fe_6O_7, is obtained, is disadvantageous to subsequent reduction in the blast-furnace or even in the open-hearth. Despite this, such a roasting may be of advantage when it is a question of preparing from a poor or impure ore a richer and purer product by subsequent magnetic treatment.

Roasting Iron Ores for Subsequent Magnetic Treatment.

The farther the utilisation of the world's store of iron ores is carried, the rarer become those ore deposits which, combined with adequate richness, are sufficiently pure for blast-furnace treat-

ment, and still much rarer are those which appear adapted for the open-hearth process, that is to say, for the manufacture of ingot iron from pig iron in the reverberatory. The question of the concentration of iron ores is becoming year by year more and more pressing for iron metallurgists. The prosperity of a country is dependent on its iron industry, but largely too on the iron ores it uses being mined in the country itself. Rich and pure iron ores still exist, it is true, in adequate quantity, but they are confined to a few places in different countries. Our excursion brings us to Spain, the country which provides all the iron-producing countries of Europe with ores of this kind. Sweden is not less rich in ores such as these, but how long will these sources of supply be available? The iron metallurgist finds it day by day a more pressing matter to enrich and improve unsuitable iron ores, and for this purpose magnetic concentration occupies the foremost place. Of the different compounds of iron with oxygen, practically only the two oxides Fe_6O_8 and Fe_6O_7 are adequately magnetic. Ferric oxide is nearly non-magnetic, and ferrous oxide cannot be produced in practice. On the other hand, the ferric oxide in red hæmatite, or in dried brown iron ore, may be readily rendered magnetic by roasting, that is to say, may be readily converted into the magnetic oxide. Three possibilities exist in this direction. When the atmosphere during roasting is oxidising in character, that is to say, when air is admitted, either the ferric oxide is converted into the magnetic sub-oxide Fe_6O_7 or Fe_6O_8, or else by the accurate roasting of carbonates a magnetic oxide is produced, or from the oxide (Fe_6O_9) by a reducing roasting a magnetic lower oxide is obtained.

Whether any one of these methods will be profitable is mainly a question of cost. The reduction is certainly rendered more difficult, the fuel consumption during reduction becoming greater, and the magnetic roasting with the subsequent treatment also in itself entails additional expenses. Probably, therefore, in most cases a preliminary preparation of the ores for the blast-furnace treatment will be out of the question. On the other hand, a pure ore, despite great cost, may in many cases prove useful in the open-hearth process, that is to say, in the oxidising fining for ingot iron in a reverberatory provided with heat-regenerating chambers, by means of which, that is, molten

pig iron is converted into molten malleable iron. One sees, therefore, that the question as to what is to be done to convert non-magnetic ores into magnetic ores is by no means one that should be overlooked, but that it is rather of great importance.

Phillips * has published an account relating to the magnetisation of the red iron ores of Birmingham, Alabama, with a view to their necessary further concentration by the magnetic process. If the observations of this writer are taken into consideration jointly with the results obtained at Allevard in France, which I have described,† one obtains from these perhaps the only cases in practice in which iron ores that are non-magnetic by nature are prepared by roasting for a subsequent magnetic treatment. The first case relates to the roasting of ferric oxide, Fe_6O_9, and the second to the roasting of the carbonate $FeCO_3$ for conversion into the magnetic oxide.

Magnetisation of the Various Iron Ores.

1. *Magnetites.*—Magnetites are of themselves magnetic, and do not therefore need to be first rendered magnetic before they can be submitted to a magnetic concentration. Nevertheless roasting may be necessary for such an ore, partly for the purposes of facilitating its further reduction in size for the magnetic treatment by rendering it more easy to break down, and partly for the purpose of eliminating the sulphides it may contain, such as iron or copper pyrites or zinc blende. Magnetites only lose very slowly their natural magnetic properties on roasting, no matter whether the roasting is oxidising or reducing in character. Only when they are maintained for a very long time at a medium red heat and with access of air will the magnetic oxide pass gradually into ferric oxide, and the ores cease to be magnetic. On this point Phillips ‡ has made detailed investigation. He made a large series of experiments and heated portions of native magnetite in a strongly oxidising flame for thirty minutes, without influencing their magnetic

* *Transactions of the American Institute of Mining Engineers*, Atlanta Meeting, October 1895.

† *Verhandlungen des Vereins zur Beförderung der Gewerbfleisses*, 1895, p. 353.

‡ *Transactions of the American Institute of Mining Engineers*, Atlanta Meeting, October 1885.

character. At a dull red heat in an oxidising flame some pieces lost their magnetic power, but regained it when raised to higher temperatures. This regaining of the magnetic properties is a fact which was noted long ago by H. Rose, who showed that on heating an iron oxide in a porcelain furnace, the oxide partly lost its oxygen and became magnetic. In a similar manner native magnetite can absorb oxygen and lose its magnetic properties, but regain these when heated to a still higher temperature, the first time through absorption, and the second through loss of oxygen. In this connection it may be pointed out that the artificially prepared magnetite does not behave so favourably as the native mineral, but loses and regains its magnetic character more readily.

2. *Spathic Iron Ores.*—From the carbonates, by suitable roasting, the magnetic iron oxide can be obtained direct. By roasting in a neutral atmosphere the "ignition" magnetic oxide Fe_6O_7 is obtained, and by roasting in a moderately oxidising atmosphere, the magnetic oxide Fe_6O_8. If, however, the carbon dioxide is once eliminated, both these magnetic oxides pass readily under the action of the oxygen of the air into the non-magnetic ferric oxide Fe_6O_9. If, therefore, it is desired to produce the magnetic oxide, the whole success depends on roasting with exclusion of air, or, if this is impossible, on reducing the air access to a minimum. The ferric oxide which is produced when there is free access of air is, however, at higher temperatures, just as decomposable again into the magnetic oxide and oxygen, as has already been referred to in connection with the native magnetites. It is possible, therefore, without endangering the magnetic character of the product, to roast spathic carbonates at temperatures as high as may be necessary to eliminate as far as possible the sulphur occurring in the spathic ores as iron and copper pyrites, zinc blende, &c.

On the other hand, this necessitates a larger consumption of fuel than would be necessary if the spathic ores were only to be converted at a low temperature into the condition of the magnetic oxide. For the preparation of magnetic oxide from the spathic carbonate, no reducing roasting atmosphere is consequently necessary.

3. *Red Hæmatites.* — Magnetic oxide can be prepared from

the ferric oxide of red hæmatites in two different ways:—(1.) By heating strongly in the absence of air. One atom of oxygen separates off in this way, and, indeed, by properly firing, two oxygen atoms may be eliminated—$Fe_6O_9 = Fe_6O_8 + O = Fe_6O_7 + 2O$. For this reduction of ferric oxide, as Phillips has shown, a relatively very high temperature is necessary, at which, if the red hæmatite contains a quartzose gangue, slag may readily form. In any case it is difficult, at the high temperatures at which this separation of oxygen takes place, to avoid a sintering, or even it may be fusion of the gangue with the ferric oxide, and the formation of an iron silicate. (2.) The second method of preparing magnetic oxide from red hæmatites depends on the roasting of the ore under the action of reducing gases, of which at low temperatures hydrogen, and at higher temperatures carbon monoxide, are most suitable in their action. To be certain, therefore, it is best to employ in the roasting a mixture of both these gases, that is to say, to roast with ordinary water-gas. The readiness with which the reduction takes place depends in both cases, with red hæmatites, largely on their more or less dense texture. Many red hæmatites are so excessively dense that just as little reduction takes place with as without the use of reducing gases, even when the ignition is long continued. On the other hand, blast-furnace practice shows that there is no red hæmatite which, given adequate time, is able to resist the reducing action of carbon monoxide, even completely down to the metallic state, and this reduction must, of necessity, be preceded by a transition through the different stages of the magnetic oxides of both kinds.

4. *Brown Iron Ores.*—Before the ferric oxide of the hydrated iron oxides can be reduced, the water must first be eliminated. The residue then behaves as a red hæmatite would, but the reduction proceeds far more readily under the influence of reducing gases, owing to the more porous character of the ore after the elimination of the water. Laboratory experiments have shown me that even from the iron oxides of the dehydrated brown iron ores, magnetic oxide may be prepared both by strongly heating with exclusion of air and by heating gently in reducing gases. Here, too, it is a question dependent on the character of the gangue contained in the ore as to which method is best to be employed. If one has to deal with ores containing no quartzose

gangue, high temperature *may* be used; if the ores contain intermingled sulphides, this *must* be employed, or in the first place the treatment must be oxidising, and then reducing in character. On the whole, for brown iron ores the method in which use is made of reducing gases at a low temperature is most advantageous on economic grounds, owing to the saving of fuel.

5. *Pyritic Ores.*—Pyritic ores, before a reduction can take place, must first always be robbed of their sulphur contents, or at least mainly so. As in any case pyrites is subjected to an oxidising roasting for the purpose of obtaining sulphur dioxide from its sulphur contents, the residue is in practice always ferric oxide, and this ferric oxide behaves exactly as that of red hæmatite, except that it is a little more difficult to reduce, owing perhaps to the presence of some residual sulphur. As is well known, iron pyrites is only then used as an iron ore when it contains copper, or perhaps, too, zinc. In addition to the chlorides of the metals resulting from the oxidising roasting of the pyrites in admixture with salt, ferric oxide also results. The former are extracted by leaching with water, and the ferric oxide remains behind in a practically pure state.*

SIZE OF THE ORES TO BE ROASTED TO MAGNETIC OXIDE.

The size of the ore pieces to be roasted to magnetic oxide is not unimportant. Before all things it is necessary, in order to obtain a good result, to have the pieces that are to be roasted as nearly as possible of the same size. It may be taken as a rule that the magnetisation takes place the more readily when the ore is in the form of small but solid pieces which do not crumble up or decrepitate on roasting, since the gas can then readily pass through the interstices, and the relatively small ore particles are rapidly converted into magnetic oxide right through their mass. A much larger size of the ore particles is disadvantageous, as for their conversion into the magnetic oxide too long a time is necessary, and since it is then uncertain whether this magnetisation has gone right through to the centres of these ore lumps. Phillips has very rightly pointed out, in opposition to the observations of Barton, that the magnetisation always

* Purple ore is pure enough for magnetic separation to be unnecessary.

takes place from the outside inwards, and never from the inside outwards.

Pulverulent or very small ore particles are excessively difficult to magnetise, since the passage of the gases through the small interstices is rendered very difficult, and the gases usually form small ways or channels, from which the conversion then begins. It is therefore very difficult to magnetise ores for magnetic preparation which have already been broken down very small, or are pulverulent—slimes, that is. All such experiments which have been made, as for instance those at Allevard,* have led to results which have not been altogether satisfactory, as the size of the pieces to be magnetised was much too small. More important than the actual size of the pieces, is the necessity for having them under all circumstances of a *similar* size, and one cannot therefore pay too great attention to ensure, by twice passing through screens before the magnetising roasting takes place, that all the ore pieces to be roasted have been brought to one and the same size.

Furnaces.

The requirements for the roasting of different kinds of ores, and especially of different ore-sizes, necessitate naturally the construction of different kinds of kilns. Lump ores are always best roasted in shaft-furnaces, in which an easy and regular passage of the ore through furnaces of circular section is obtained. The section of the furnace should widen slightly from the throat downwards, in view of the gradual heating of the ores and their expansion. Inversely this leads also to a more regular upward passage of the furnace gases through the ore. It is therefore a question of causing the ore to pass through two different stages, first heating them, and then reducing them if they are oxidised, provided, of course, that they are red or brown hæmatites. This must be effected by using gas in two ways, partly as fuel and partly as the reducing agent. As Phillips has observed in his description of the roasting of red hæmatites, the gas for heating purposes is best introduced into a combustion chamber in which it is burnt around the furnace, so

* *Verhandlungen zur Beförderung des Gewerbfleisses*, 1895.

that only the flame enters the furnace. It need hardly be mentioned that gases cannot be burnt without the presence of a not inconsiderable excess of air, and attention has therefore to be given to seeing that in the heating of the ore oxidation is as far as may be avoided. Only in the case of red hæmatites which are to be reduced by the splitting-off of oxygen at a high temperature, is a temperature to be employed which may be as high as is possible of attainment, and in this case it may be a matter of indifference whether an excess of oxygen is present or whether this is absent. In the case of spathic ores the only thing that is necessary is heating in the absence of air, with no subsequent oxidation, although here too the treatment with reducing gases can only be advantageous in character. The reducing gas, whether ordinary producer or, and better, water gas, must then be passed into the heated ore from a lower level, and caution is necessary to ensure that no air can enter. The openings which are to be employed for the withdrawal of the roasted ore from the furnaces must therefore be capable of being closed perfectly air-tight during the roasting, and the brickwork, too, must be built so as to withstand the passage of air through it. To be able, however, to readily withdraw the ore, the reducing gas must be passed into the furnace at a level somewhat above that of the withdrawal doors. One obtains in this way the advantage that the gas in its upward passage at the same time cools down the hot ore, with the result that this arrives at the withdrawal openings in an almost cold condition. The space between the entry of the hot burnt gases and those used for the reduction ought never to be small, as is often the case in Swedish calciners.*

In the case of pulverulent or fine ores, the use of shaft-furnaces is not advisable, and it is better in such a case to employ zig-zag furnaces, such as were used at Allevard, or channel-furnaces with inclined beds. Still care should as far as possible be taken never to have to deal with such fine ore, but rather with ore of a coarser character.

* One of the principal conditions for properly roasting iron ores into the magnetic state is the keeping of a right temperature in every part of the furnace. Since the Le Chatelier pyrometer is made in the form described by the author (*Stahl und Eisen*, 1896, September), all difficulty in controlling the temperature is obviated, and the instrument may unhesitatingly be relied upon for this purpose.

CONCENTRATION OF THE MAGNETISED ORE.

The magnetised ores, after the roasting, must be submitted to concentration, which may in the first instance be mechanical in character, to separate from each other the ore particles of different sizes, and then magnetic, or it may be magnetic from the very commencement. This must be entirely dependent on the character of the ore as regards admixture of gangue and iron oxides. The finer the state into which the ore is brought for magnetic separation, the more satisfactory will the progress of that separation naturally be, and the better will be the yield. The fine state of the ore has however, in spite of this, various drawbacks. In the first place, as has been mentioned above, the magnetisation is, as a rule, by no means regular, and in the second, such finely divided ores can only be added with advantage in quite small quantities to the blast-furnace charge, former experience in this direction placing this maximum at 12 per cent. All methods, too, of converting this fine ore again into larger lumps are too expensive to be, at least generally, commercially satisfactory. If, therefore, the ore is to be used in blast-furnace practice, such very small ore must, as far as possible, be avoided, and the size should be kept at about that of hens' eggs. On the other hand, small and even pulverulent ore may very well be utilised in the open-hearth, and it has for this field of operations, I think, a very wide scope indeed, for the scrap which is now necessary for the conversion of the pig iron into ingot metal in the open-hearth process is becoming year by year more difficult to obtain and more expensive to purchase, and it might very readily be entirely replaced by oxides. If the ores powder up readily on charging into the bath of pig iron, they may be enclosed in cases of sheet iron or paper (cartridges).

Very few ores are of themselves pure enough for the open-hearth process, and they cannot either be converted into an adequately pure form by mechanical concentration, so that there is scarcely any other way of purifying them which could prove itself commercially economical except the method of magnetic concentration, which, if the ores are not magnetic, must be preceded by a magnetic roasting.

DISCUSSION.

Professor WEDDING added (by the invitation of the President), that the object of his paper had been not to show the different kinds of separation of ores which were magnetic of themselves, but rather to explain how to make ores magnetic which were not so naturally; and he had brought forward two different magnetic oxides. Scrap was often, especially in Germany and in England, very expensive. If the open-hearth process was employed, it would in future often be necessary to use very rich and pure ores instead of scrap. The ores which were needed were very scarce, and it was therefore necessary to make rich ores out of ores which were not rich enough of themselves. For that purpose it was necessary to roast at certain temperatures in order to make the ores magnetic, and then have the opportunity of separating the rich part from the poor, but the temperatures should be accurately measured.

Mr. Le Chatelier had invented a pyrometer which was useful for that purpose, and he (Professor Wedding) had improved it somewhat, so that it could be employed for different metallurgical operations. It had been made accurate since Mr. Heräus of Hanau had made pure platinum and an alloy of platinum and 10 per cent. of rhodium. It was difficult to make the pure metal, but Heräus now made it quite pure. He melted together on one point—a very small point—the two metals named. The wires went up, and were connected with copper wires so as to have a small resistance, but as it was possible that in the connection of copper and platinum wire another thermo-current might originate, it was necessary to cool those places. It was easily done in a box of wood or small vessel, and, if necessary, flowing water. There were no other thermo-currents than the original one of the instrument.

The first thing Heräus did was to place the thermal element in a tube of porcelain of the highest melting-point. Although the easiest experiments were made to measure the heat of gases, a difficulty was experienced because the porcelain went to pieces. If taken in melted metal, it fused. He had tried many methods,

and had at length used china-clay, very rich in aluminium, which could be used up to 1600°. It would, however, not answer in fluid metal; he therefore tried a mounting where he got the porcelain tube in asbestos. Asbestos could be placed in the tube as well as outside. The pyrometer could then be used in such a manner that the porcelain might crumble in pieces, but the pieces would remain in their places. He had used the pyrometer several times and purposely broken it in pieces, and all was in right order. It could be used as a pyrometer not only for every furnace to bring it to any desired temperature, but also in fluid metal.

It was very disagreeable to him to find at first that the pyrometer swam flat, so that the wires dropped into the fluid metal and were destroyed. He then adopted another plan, which succeeded. He made the lower part of the pipe widening as a ball or cylinder, and into that wider part he poured tungsten mixed with a little charcoal, so that it did not weld. They had now, therefore, a pyrometer like a thermometer for ascertaining the temperature of a water-bath. The instrument swam vertically, the wires being taken over rolls and connected with the wires of the galvanometer. The galvanometer could be placed in the office, so that the manager could see if the temperature for casting steel was too high or too low. His friend Professor Roberts-Austen had made some experiments in other directions at the Mint. He had a Chatelier pyrometer to which he added a photographic apparatus, and by a lens showed the state of the needle in the photograms. He had thought it worth while to mention the subject, because if it was desired to make non-magnetic ores magnetic, it was of the greatest importance to have right temperatures.

Mr. E. P. Martin, Vice-President, said that Professor Wedding had probably had a large amount of experience in calcining ores. In this district (Bilbao) there was probably nothing of greater importance than the proper utilisation of the enormous amount of spathic ore now being gradually worked there. Unfortunately, there was one point which militated against its general use—viz., the large amount of sulphur left in the ore after calcination. When the Institute visited America, the members saw at the

Cornwall Works, in Lebanon County, Pennsylvania, a special kiln called the Davis Colby kiln, which, he believed, enabled magnetic ore to be utilised, which, under ordinary circumstances, contained far more sulphur than could possibly be worked in the furnace and make good pig iron. He thought he was within the mark in saying that the ore contained $2\frac{1}{2}$ per cent. of sulphur, and after roasting it was reduced to about 0·12 per cent. If, by using a similar class of kiln in this district for spathic ore, they could obtain the same or a similar proportionate reduction of sulphur after calcination, there would be still left in this district a large supply of first-class ore fully equal, after such calcination, to the Campanil ore, which was now almost worked out. He should be glad if Professor Wedding could give any information as to whether such a kiln could be used in the district with advantage for calcining spathic ore; also, whether he had tested his pyrometer in a Siemens steel furnace, or in a furnace melting foundry iron.

Sir Lowthian Bell, Past-President, said he had a good deal of experience in endeavouring to get sulphur out of iron, but it was for the purpose of using the sulphur, and having no regard to the iron with which it was united. There was no difficulty at all in reducing ore containing 30 or 40 per cent. of sulphur to 2 or 3 per cent. The difficulty to be contended with was that when the iron was all peroxidised—which meant the evolution of a certain quantity of heat—and the sulphur had been expelled, they were unable to maintain a temperature high enough to get rid of the remaining 2 or 3 per cent., and the consequence was that it was left in the ore taken away for the extraction of the copper it contained. The difficulty to be avoided in calcining the ore for the blast-furnace by means of coal was to avoid fritting the mass by too much heat. If they once began to fuse ore containing 2 or 3 per cent. of sulphur, it would be found very difficult to get rid of this element. In that respect he had no doubt that the apparatus mentioned by Professor Wedding would be useful. The question was in what way the heat was to be applied. It would have to be done very carefully for the reason he had just mentioned.

Mr. J. E. Stead, member of Council, said that the analysis of spathic ore given by Mr. Gill at the end of his interesting paper showed that there was a considerable quantity of lime in such ore. The presence of lime in ore when subject to calcination in the presence of sulphur was a bar to the complete removal of the sulphur, for the simple reason that it was a base which immediately fixed any sulphurous or sulphuric acid as soon as it formed, and which could not then be removed. In purple ore it was possible to remove almost the last traces by making it in bricks and burning it to a white heat. The action of peroxide of iron in the absence of lime converted the remaining sulphide of iron into sulphurous acid or sulphuric acid, and it escaped. But when there was a sufficiently large quantity of lime, it not only prevented the removal of the sulphur present in the ore itself, but it would absorb the sulphur from the fuel used for calcining; consequently it was often found that in certain ores if a large quantity of lime was in the ore, there was more sulphur in the calcined material relatively to the iron than there was before calcination. In the spathic ore there was 2½ or 2¼ per cent. of lime; in the calcined state sulphuric acid existed to the extent of 0·68 per cent.; probably some of the lime would combine with the silica in the ore, and thus be prevented from combining with sulphuric acid; but if any free lime remained, it would retain sulphur, which could not be got rid of unless the process could be modified in some way, but what modification was required was not apparent.

Mr. G. J. Snelus, Vice-President, was quite able to corroborate what Mr. Stead had said from his experience in another direction. Many years ago the idea of fixing sulphur in coke-ovens by adding lime to the coal was brought forward. The process was still carried out by Messrs. Bain at Harrington, and it was tried at the West Cumberland coke-ovens for a considerable time, but he invariably found that the sulphur left in such coke was very much higher than that got in coke without the lime; and for that reason he (Mr. Snelus) objected to the process. But in the blast-furnace it appeared that the sulphur so fixed with the lime had not the same injurious effect, for they were still using the same coke at Messrs. Bain's; they had continued to do so for

years with a beneficial effect. Their iron was not a sulphury iron; the coke was a sulphury coke, and by adding lime to the coke and burning it, the sulphur was fixed in the way mentioned by Mr. Stead. There was more sulphur in their coke than there was in coke made without the lime.

Professor WEDDING said his experience was the same as that of Mr. Martin and Sir Lowthian Bell, and probably, therefore, the plan described would not be adopted for blast-furnaces, because if the sulphur was removed, either there would be an ore without silicon and lime, or it must be in a powdered state, neither being good for the blast-furnace. As far as he knew, the highest percentage of fine ore used in a blast-furnace was 12 per cent. If it were so made that they could roast first to make the ores magnetic, separating them from the silica, and afterwards roasting them with excess of air at high temperatures, the sulphur might be got rid of; but he thought that in practice the process would be too expensive. As to the question whether it could be done on a large scale, he had only made it in cast iron and in the ladle, but he was certain that it could, without difficulty, be used in the open-hearth furnace.

The PRESIDENT proposed a cordial vote of thanks to Professor Wedding for his interesting contribution, and the following paper was read:—

THE MANGANESE ORE DEPOSITS OF NORTHERN SPAIN.

(WITH NOTES ON SOME OTHER SOURCES OF SUPPLY.)

By JEREMIAH HEAD, M.Inst.C.E., F.C.S., &c.

In response to a request from our President that I should prepare for this meeting a paper on some subject connected with the mining industries of the country which has just given us so cordial a welcome, I have ventured to select the above subject as one likely to be of interest to all concerned in the production and manipulation of iron and steel.

About four years ago I was instructed by a client to proceed to Spain, and examine and report upon four manganese ore concessions, three of which, called Mercurio, Maude, and Excelsior, were in the neighbourhood of Arenas de Cobrales, 45 miles (as the crow flies) west by south of Santander; and the remaining one, called Magenta, 20 miles further to the west, and 6 miles south by west of the ancient ecclesiastical town of Covadonga.

Torrelavega, a station on the Santander and Madrid railway, 14 miles from the former city, was our starting point. Further transit by railway not being available,* a carriage was hired to proceed *vià* Comillas, San Vicente, and Unquera, to Pañes, 40 miles distant. From thence to Arenas, a distance of 18 miles, we travelled on horseback, an extra animal being loaded with our baggage. Mr. R. E. Stone of London, who is interested in Spanish minerals, and my son and partner, Mr. A. P. Head, accompanied me. We found the main roads—which in Spain are constructed and maintained by Government out of local taxes—exceedingly good, but the by-roads are not entitled to favourable comment.

Towards Arenas the scenery becomes exceedingly grand. The road being cut out of precipitous limestone cliffs, is in parts not

* A branch line from Torrelavega to Llanes has been commenced, but it will be some years before it is completed.

a little dangerous, especially to strangers travelling after sunset, owing to occasional land-slips and fallen boulders. Arenas is a small village, characteristically Spanish. We were hospitably entertained in the fonda or inn, our horses being stabled underneath in true Spanish fashion. (See Plate 45.)

Leaving our animals at Arenas, and the three mineral concessions near it for subsequent investigation, we pushed forward by hired carriages 25 miles to Covadonga (see Photo No. 2), the entire 83 miles (by road) from Torrelavega having taken three days to accomplish. By the kind intervention of a prominent ecclesiastic, we were housed for the night at the hospice, the only place available for the purpose, and next morning we proceeded on fresh mounts to visit the Magenta concession, and certain other manganese ore mines in actual operation which adjoin it.

Covadonga is about 1000 feet above sea-level; the altitude of the Magenta concession is 4000 feet.* Further to the south are much higher elevations of bare limestone rock (Plate 44) forming a range which runs nearly east and west, and is called the Sierra de Covadonga. Away to the east, where the Arenas group are situated, the same range is known as the Sierra de Dobros. Parallel with this range, and still further to the south, are the magnificent heights called the Picos de Europa, some of which attain to an elevation of at least 8000 feet. The spaces intermediate between these ranges are occupied by numerous spurs and basin-like valleys.

Throughout the Dobros range, clearly traceable in several places, and for considerable distances, is a vertical chasm or fissure, three to four feet wide, and which is, or has been, filled up with manganese ore, more or less interspersed with limestone. This fissure is known locally as the "Filon" (or vein); it is said to extend at least twenty miles. I cannot say I actually saw it at the Covadonga end, but at the Arenas end it is clearly visible in several places (see Plates 50, 51, 52, and 53).

Along the supposed line of the vein, the range includes a number of small valleys, which are more or less filled up with débris or drift from the rocks above. Where such accumulations are near to, and below the vein, they usually contain a quantity

* It is reached, at present, by a more or less precipitous mountain path eight miles long, which, near the summit, passes by the small lake Enol.

of manganese ore in lumps or nodules, which are no doubt the products of its gradual disintegration. Such a deposit is locally known as a "bolsa" (or pocket).

Applicants for mining concessions always seek to include in their holdings part of the vein, or some of the drift which has proceeded therefrom, or both. In the former case the mineral, being compact and solid, has to be drilled and blasted; in the latter case it may be dug out, and then hand-picked, and cleaned or washed.

As the Magenta concession (Plate 47) was at the time of my visit, and I believe still is, entirely undeveloped, and derives its value from the circumstance that it is on the line of the vein, and that drift ore has been found in test workings, and that it adjoins another concession also on the vein, known as Asturiana, which has been somewhat extensively worked, I propose to give some particulars of the latter as the best example of a manganese ore mine in the north of Spain.

The Asturiana mine (or group of concessions) was originally opened out in 1874 by Señor Ferdinando Corvellain, a Belgian, who worked it until 1886, when he was succeeded by Señor Labra, who was in occupation at the time of my visit. There were then three openings or pits. The principal one was 75 feet long by 48 feet broad by 48 feet deep. The surface soil appeared to be a kind of boulder clay. Below that, a few feet of blue clay containing limestone nodules was visible, and still lower a red ferruginous clay, known as "red-cap," containing lumps of manganese ore mixed with similar lumps of iron ore. This was the "bolsa" which was being worked at the time. The lumps of manganese ore, after being brought out, were hand-picked and cleaned with chisel-hammers by women sitting on the ground (Plate 48). At the bottom of the pit a hard rock could be felt by aid of a sharp-ended crowbar, and this I was informed by the "capitas" (or mine-captain) was the vein itself.

A troup of donkeys in charge of a woman, each one having a pair of panniers, carrying 200 lbs. in all, took the ore down the mountain path (eight miles) to Covadonga. Thence it was transferred to bullock-carts holding from 2 to 2½ tons each, and conveyed to Rivadesella, the port of shipment (Plate 49) twenty-two miles distant. The Government has already com-

menced a circuitous cart-road twelve miles long, from Covadonga to Lake Enol close to the mines. This when finished will abolish donkeys and panniers, and greatly cheapen the cost of transit. But roads in Spain are not built in a day.

Table No. I. gives an approximate estimate of the cost of working at the Asturiana mine at the time of my visit, including delivery of the mineral to a British port. The figures would apply equally to the Magenta concession. In the item for extraction the cost of exploiting and developing in barren ground is not included. On the other hand, the application of modern mining appliances and methods, and an extensive increase in the output, would be likely greatly to diminish the cost of extraction. Mining labour is plentiful at—

For men	1s. 4½d. to 1s. 10½d. per day.
For women	8½d. to 10½d. per day.

TABLE I.

	Distance.	Cost per Ton (2240 Lbs.). £	s.	d.
	Miles.	£	s.	d.
Extraction	...	0	14	0
Rent at 10 pesetas per hectare per annum	...	0	0	3½
Government tax at 1 per cent. on value of ore at mines .	...	0	0	2½
Administration and trade charges, say	...	0	8	0
Transport,* mines (3000 feet elevation) to Covadonga (1000 feet elevation)	8	0	15	8
Transport, Covadonga to Rivadesella (sea-level) . .	22	0	7	0
Putting f.o.b., say	...	0	2	4
Freight and charges to British port (including insurance), say, ...	...	0	10	0
Total	...	2	17	6
Value † of 51-unit ore at 1s. 3d. per unit	...	3	3	9
Difference, being profit, per ton	...	0	6	3

From the custom-house entries at Rivadesella, where the whole of the manganese ore from the Asturiana mine, and no other,

* When the new cart-road from Covadonga to the lake is completed the fifth item, viz., 15s. 8d. for pannier transport, will be reducible by about 10s. per ton by the use of bullock-carts over the first eight miles of the route.

† The market value when the estimate was made. It is now about 1s. 1d. per unit for high-grade ore.

had been shipped up to 1892, and from information obtained from the mine-captain, I estimate that 12,500 tons represents the entire quantity obtained from it up to that time, and 1200 tons as the maximum yearly output. It must be remembered, however, that on account of the high altitude, eight months in each year is the utmost time available for working, in open pits.

From the Asturiana mine, and the adjoining Magenta concession, I collected ten specimens of ore which on my return I sent to Messrs. Pattison and Stead for analysis. I requested them to mix them and give me the average of the whole.

Table No II., column 1, gives the result. Column 2, which I have added for purposes of comparison, gives the approximate composition of ordinary good manganese ore, such as finds a ready market in England at about 1s. 1d. per unit now, but then at 2d. per unit more.

TABLE II.

	1. Average Analysis of Asturiana and Magenta Mines.	2. Ordinary Manganese Ore, Marketable at about 1s. 1d. per Unit.
	Per Cent.	Per Cent.
Metallic manganese (Mn)	58·35	50 to 52
Metallic iron (Fe)	1·10	...
Silica (SiO_2)	0·90	5·0 to 9·0
Phosphorus (P)	0·01	0·03 to 0·15
Copper (Cu)	trace	0·05

Messrs. Pattison and Stead say in a footnote that the Asturiana samples indicate a splendid quality.

The inspection of the Asturiana and Magenta concessions having been completed, we returned to Arenas, and next morning proceeded on horseback to examine the three other concessions. They are situated in a line running nearly east and west, Mercurio being furthest to the east, then Maude, and lastly Excelsior. (See Map.)

Arenas is about 500 feet above sea-level. Crossing the river Cares, we rode up an excellent bullock-cart road (though now out of repair), made by the last owners of the mines, to a point some six miles from Arenas, and at an elevation of 2650 feet. Here an adit 490 feet long, 8 feet high, and 6 feet broad had been

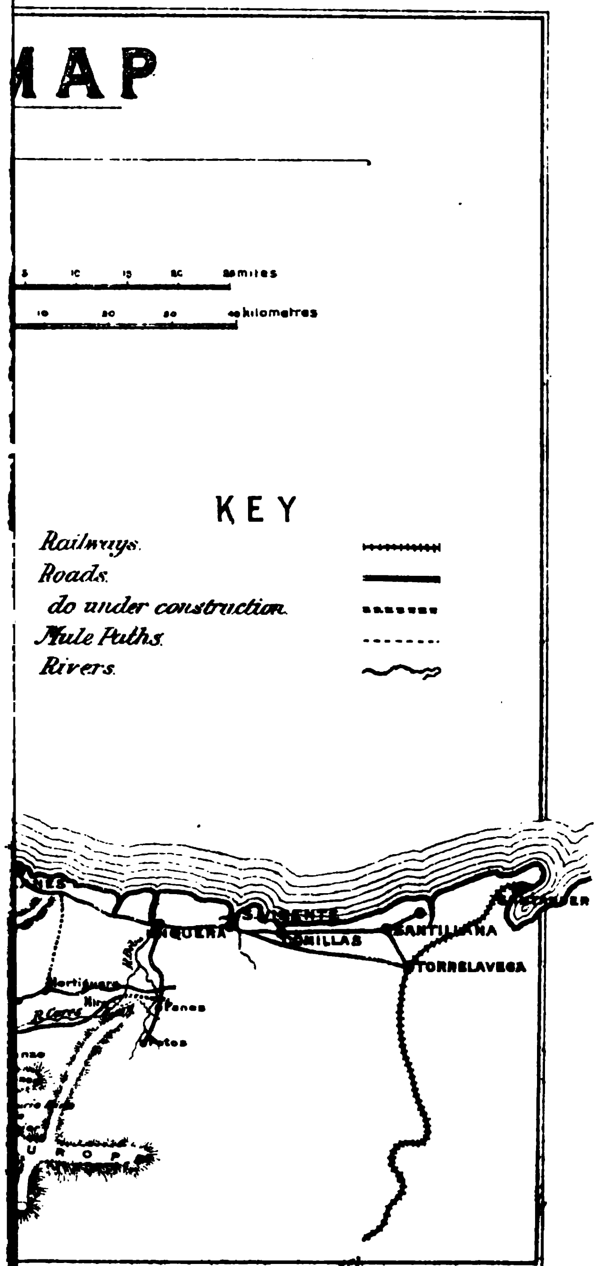
driven into the mountain in a south-westerly direction in order to intersect the vein. The vein was found; but proved to be, at that particular place, only one or two inches thick, and was adjudged not worth following up.

Leaving our horses at the mouth of the adit, we ascended on foot by various zigzag mountain-paths, till we found ourselves among the summits of the Sierra de Dobros range. The general features of the rugged country around us were similar to those we had encountered among the heights of the Sierra de Covadonga, which now lay twenty miles to the west of us. There were the same bare limestone rocks, enclosing a series of crater-like basins filled with drift composed of a matrix of soil, containing lumps split off and washed down from higher levels. The limestone rocks themselves, which were picturesque in the extreme, were worn and furrowed into multitudinous fantastic forms, and bore every sign of continuous though slow disintegration, from the action of snow, ice, and rain. In many cases they were hollowed out into stalactitic caverns which, from the footprints within them, appeared to be the resort of various animals.

The first of the summit basins we entered was one known as the "Vega de Dobros." The elevation of the lowest part was 2700 feet. Our guide, an old "capitas," said that the vein ran through it, but it was not clearly visible. There were three or four small pits indicating former exploitations, which were said to have been made by one Louis Mason; but clearly nothing of importance in the way of mining had been done.

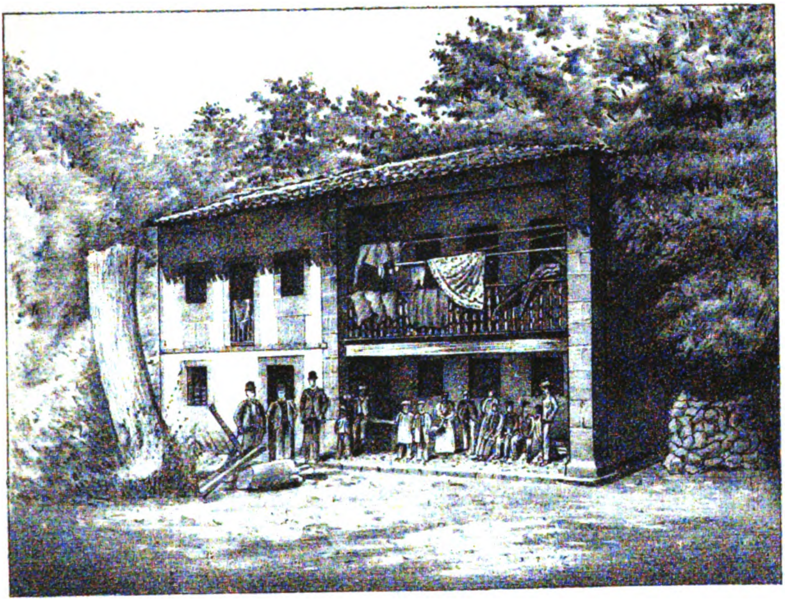
Between the Vega de Dobros and the first of the three basins included in the Mercurio concession, is a ridge which we had to cross, and the top of which is 3120 feet above sea-level. A natural tunnel (which, however, was impassable at the time owing to an accumulation of water) passes through the ridge. The western mouth of the tunnel opens upon the first basin of the Mercurio property (Plate 52). In each basin the vein is clearly visible (Plates 50, 51, 52, and 53).

Inasmuch as the evidences of previous mining operations, to any extent worthy of the name, are confined (in this group) to the Mercurio and the adjoining Maude mine, it may be convenient to allude here to their past history. From time immemorial the existence of the vein has been known to the natives,



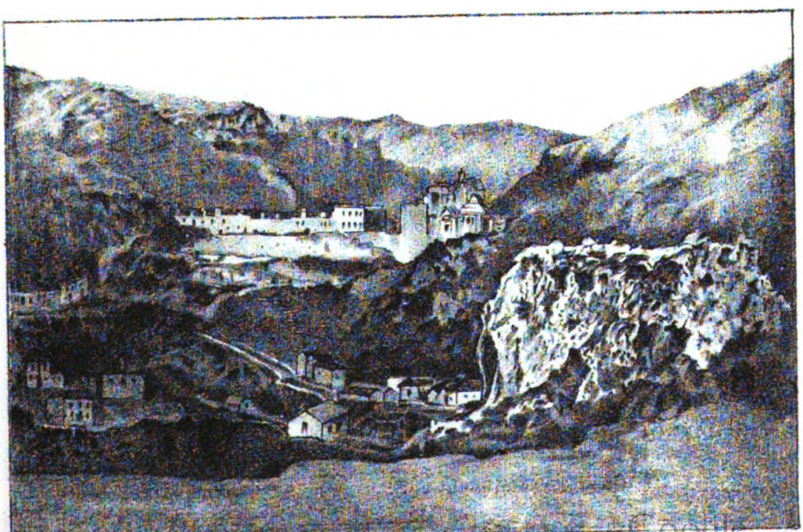
Ballantyne, Hanson & Co. Edinburgh & London.

Plate XLV.



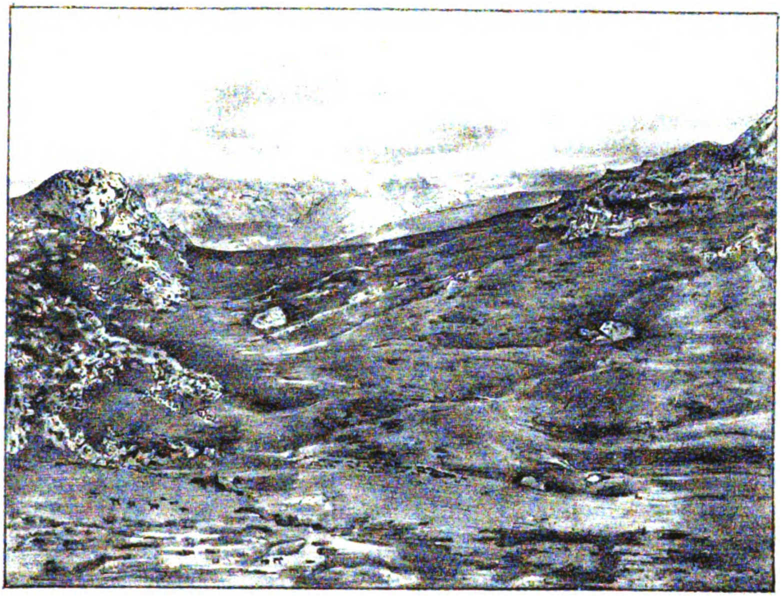
"Fonda" or Inn at Arenas.

Plate XLVI.



Covadonga Cathedral.

Plate XLVII.

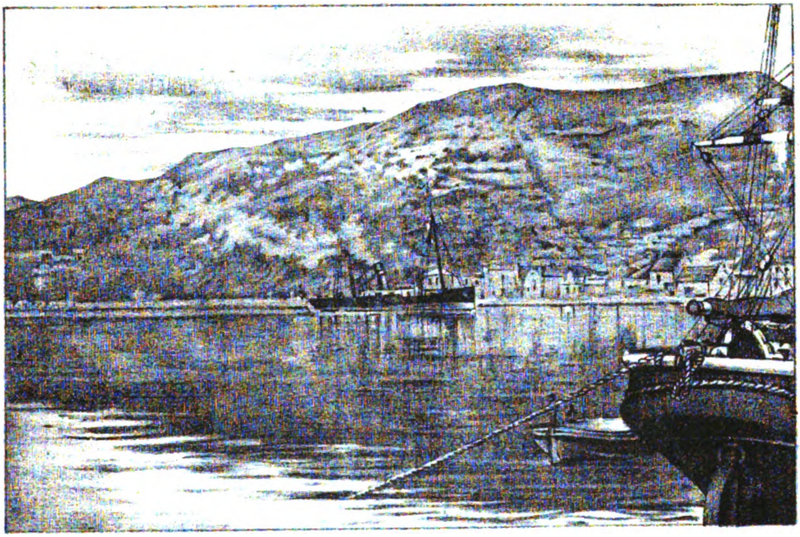


Magenta Property, looking East.

Plate XLVIII.

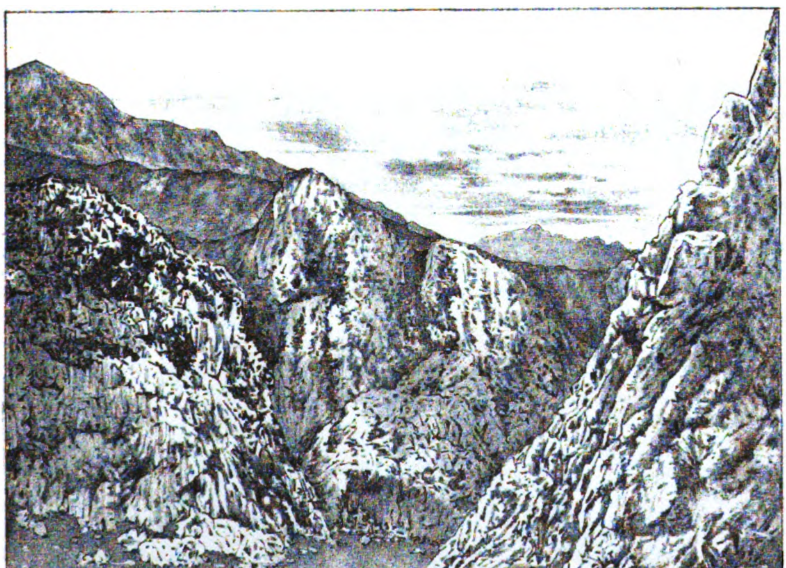
Women Hand-picking Ore on Asturiana Property. Pannier Donkeys seen on right.

Plate XLIX.



The Port of Rivadesella.

Plate L.



General View of Excelsior Property, looking West.

PLATE LI.

Ravine formed by working out Filon on Maude Property, looking West.

PLATE LII.

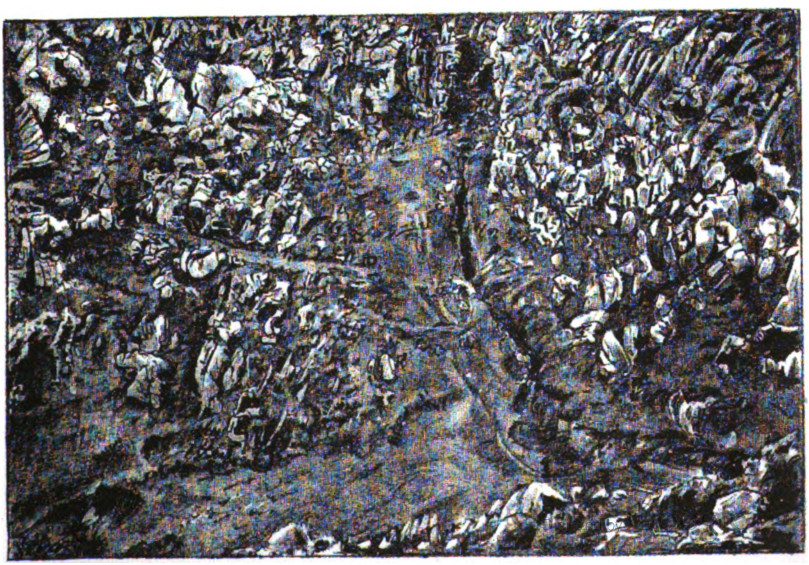


Plate LIII.

Second Basin of Mercurio Property, looking East.

and in a small and spasmodic way it has been worked by them. But they never had much capital or mining skill, and never went to work systematically or far below the surface. As soon as winding or pumping tackle was required, or any barren work had to be done, they always filled in the débris above the face of the mineral, and began afresh somewhere else.

The Vielle Montagne Zinc Company of Liége, Belgium, being interested in calamine and blende mining in the locality, were induced many years ago to acquire and develop these manganese mines. They made the bullock-cart road from Arenas to a depôt near the mouth of the adit I have alluded to; also an aërial tramway from the upper part of the Maude mine to the said depôt; also at least four vertical shafts in the vein, and four adits. They also built various offices, shops, and workmen's houses at the top level of the mines. For a time they appear to have met with fair success; but the most accessible portions of the vein having been worked out, and the value of manganese ore having fallen considerably, they suspended operations twenty-two to twenty-four years ago, and nothing has been done there since.

The vein has apparently been worked out to a depth of 20 to 30 feet in the three Mercurio basins, and the chasm so formed is now more or less filled up with débris and overgrown with grass and ferns. Manganese ore in its original position is, therefore, not very easy to find. Still our guide broke off some pieces, and I collected various nodules from the adjacent pockets.

Proceeding westwards, we came upon another series of basins, throughout which the position of the vein was plainly discernible. This series of basins constitutes the most important portion of the Maude property. Near the boundary line is a square shaft sunk in the vein. The shaft is about 64 feet deep from the surface to the level of the water standing in it. It is believed to have been originally 120 feet deep in all. Just above the water-level a short adit has been driven from the shaft in a nearly northerly direction to daylight and the mountain side.

A little farther to the westward, at an elevation of 3100 feet, is the cable station whence the aërial tramway formerly received its loads for conveyance to the depôt beside the bullock-cart road, 350 feet lower down, and about 300 feet in a northerly direction.

Near the cable station is the mouth of another adit which has been driven into the mountain in a nearly westerly direction, for about 180 feet. The object of this was probably to cut the vein and then, by means of branches right and left, collect the mineral and focus it at the cable station for delivery to the depôt.

The next day we returned in the same way to the cable station, and ascending on foot a steep mountain-path behind it, we there came upon another basin in the Maude property, the position of the vein being again clearly visible, running east and west as before.

Another shaft called "Pozo Escalon," about 150 feet deep, had been sunk here, probably the one to join which the cable station adit was driven. Further to the west another shaft 20 feet deep was met with, and still further a much larger one called "Pozo des Bezararas." Both these shafts are in the line of the vein. From the bottom of the last-named one, which was about 60 feet deep, an adit appeared to lead off in an easterly direction, but how far it had been continued it was impossible to say.

Near it are the ruins of about five buildings which were erected and used by the Vielle Montagne Company for the accommodation of their work-people.

The thickness of the vein seemed to be from 3 to 4 feet wherever I was able to measure it, and this thickness remained about constant at different depths.

Passing on still further to the westward over a separating ridge, we came upon a triangular basin. On the eastern slope of this is the mouth of an adit entering the said ridge, and driven in an easterly direction for about 100 feet. No work has been done, but on the northern side of a mountain called Cueto Lovero, still further to the west, some ancient workings can still be seen. The vein is believed to pass through the triangular basin, though covered up and invisible. The drift soil certainly contains nodules of manganese ore. Plate L., taken from just above the mouth of the adit, shows the Cueto Lovero.

Various samples collected from the Mercurio, Maude, and Excelsior properties were sent to Messrs. Pattison and Stead on my return, with a request that they would make an average analysis. The following is their report:—

Mercurio, Maude, and Excelsior Mines.

	Average of Samples. Per Cent.
Manganese	54·81
Iron	0·70
Silica	6·30
Phosphorus	0·08
Copper	nil

Messrs. Pattison and Stead say that these samples also indicate "splendid quality."

My estimate of the cost of working at the Mercurio, Maude, and Excelsior mines, and delivery of the material to a British port, at the time of my visit, was as follows. (This estimate does not include any barren work which may be necessary in exploiting or developing the mines):—

	Cost per Ton (2240 lbs.). £	s.	d.
Extraction	0	14	0
Rent, 36 hectares at 10 pesetas per annum (£12, 8s.), which on an output of 1500 tons per annum = say	0	0	2
Government tax, at 1 per cent. on value of ore at mines (say £1, 2s. 5d.)	0	0	3
Administration and trade charges, say	0	8	0
Transport, mines (3250 feet elevation) to cable depôt (2750 feet elevation) by donkeys, say 1½ miles at 2s. per mile	0	3	0
Transport, cable depôt to Arenas (500 feet elevation) by bullock-cart, 1-ton loads at 8d. per ton per mile, 6 miles	0	4	0
Transport, Arenas to Unquera (sea-level) by bullock-cart, 2-ton loads, 32 miles at 4d. per ton per mile	0	10	8
Putting f.o.b., say	0	2	4
Freight and charges to a British port (including insurance)	0	10	0
Total	2	12	5
Value of 51-unit ore at 1s. 3d. * per unit	3	3	9
Difference, being profit per ton	0	11	4

If the aërial tramways were reinstated, or a wooden shoot lined with iron plates substituted, and if the principal adits were completed so as to enable the mineral to be brought to the bullock-cart depôt without the intervention of pannier donkeys, then something like 2s. 6d. per ton might be saved out of the above cost.

I have assumed that the ore from these three mines (in case

* See p. 142, note †.

they are ever re-opened) will be shipped at Unquera, to which port it would be taken *viâ* the new road. Ships carrying 300-ton cargoes can enter and leave Unquera. There is a depth of 11 feet of water on the bar and 8 feet at the quays (presumably at high-water). Small French sailing vessels, working at low freights, are the kind of craft most easy to obtain to convey the mineral thence direct to British ports. The actual loading is usually done by boys and girls with baskets. Shipping at Unquera in this way has been continuously carried on for more than thirty years.

Unquera is considered by those having local experience to be the most suitable port for shipment from the Arenas group of mines. But there are others where the facilities are on the whole not greatly inferior.

Rivadesella can accommodate vessels carrying from 500 to 600 tons, but it is considerably further (42 miles) from Arenas, and the road to it passes over a mountain range involving a long and somewhat steep ascent. Whereas the road to Unquera is a nearly continuous descent throughout the entire distance.

Seven miles beyond Unquera is San Vicente. This is almost as good a port as Rivadesella, ships carrying 400 to 500 tons being able to enter. The extra cost of road transit as compared with Unquera would be about 2s. 4d. per ton.

Llanes, when the new road *viâ* Hortiguera is completed, will be by far the nearest port of shipment to Arenas, but the harbour is not a good one.

The position of the manganese ore industry in Northern Spain, as I have endeavoured to describe it, is what it was in the autumn of 1892. Since then considerable progress has been made as regards the Asturiana deposit at the Covadonga end of the vein. About the end of 1893 Señor Labra ceded his rights to a London company entitled "Asturiana, Limited," who determined, by boring and sinking, to thoroughly test the quantity, quality, and value of the deposit. For information as to the operations of this company I am largely indebted to a paper read before the Institute of Mining and Metallurgy on March 6, 1895, by Mr. J. A. Jones, and to a statement issued by the company itself two years later, which contains a report by Messrs. Edward Riley & Co. of London.

When describing the main pit of the Asturiana mine, from a

pocket in which mineral was being drawn at the time of my visit, I said that the bottom or floor of the pit seemed composed of a hard rock which could be felt by aid of a pointed crowbar, and which was believed by the mine-captain to be the vein itself. This rock has now been bored to a depth of 47 feet, and proved to be mainly composed of manganese ore.* The boring was discontinued without reaching the limestone bed rock.

Table III. gives (on the authority of Mr. A. J. Campbell, Assoc. R.S.M.) the results of twenty-one borings made by the Asturiana Limited. They indicate the existence of an extensive and valuable deposit of manganese ore, sufficient to justify the introduction of modern methods and appliances, and to yield a large annual output for many years.

TABLE III.

ASTURIANA MINE.—*Thickness of Strata passed through.*

	Boulder Clay.	"Redcap" containing Manganese Ore.	Remarks.
Bore-hole No. 1 . .	13 ft. 3 in.	24 ft. 9 in.	Entered Limestone
„ 2 . .	43 ft.	8 in.	„
„ 3 . .	42 ft. 4 in.	22 ft. 8 in.	„
„ 4 . .	12 ft.	33 ft.	„
„ 5 . .	11 ft. 6 in.	6 in.	„
„ 6 . .	8 ft.	11 ft. 6 in.	Stopped in Mn ore
„ 7 . .	7 ft. 6 in.	8 ft.	„
„ 8 . .	21 ft.	...	21 ft. in Limestone
„ 9 . .	17 ft.	18 ft.	Stopped in Mn ore
„ 10 . .	25 ft.	11 ft. 6 in.	Entered Limestone
„ 11 . .	35 ft.	58 ft.	Stopped in Mn ore
„ 12 . .	50 ft.	14 ft.	„
„ 13 . .	56 ft. 10 in.	14 ft.	„
„ 14 . .	103 ft. 1 in.	1 ft. 6 in.	„
„ 15 . .	50 ft.	14 ft.	„
„ 16 . .	15 ft.	62 ft. 6 in.	Entered Limestone
„ 17 . .	118 ft.	2 ft.	Stopped in Mn ore
„ 18 . .	105 ft.	6 ft.	„
„ 19 . .	...	47 ft.	„
„ 20 . .	94 ft.	13 ft.	„
„ 21 . .	113 ft.	2 ft.	„

Under these new and encouraging circumstances, the tardy progress of the new road from Covadonga to Lake Enol becomes especially provoking. Already there are proposals afloat to establish (rather than wait longer) an aërial tramway from the

* See boring No. 19.

mines to Covadonga, which need not be more than four to five miles long, and a narrow-gauge railway from thence to Rivadesella, alongside the existing road. These works would require time and capital;[1] but in view of the now well-assured traffic, they would in all probability eventually pay well.

On the assumption that an aërial tramway will be made forthwith to Covadonga; that an output can be obtained of 125 tons per day for 160 days per annum, or 20,000 tons per annum; that a cubic metre of redcap or ore-bearing mineral will yield 30 per cent., or 1·4 tons of ore, and will entail the removal of not more than three cubic metres of over-burden; and that conveyance to Rivadesella will still be done by bullock-carts, Mr. Jones is of opinion that the cost price of the ore delivered to an English port may be brought down to £1, 17s. 7½d. per ton, or say £1 per ton below my estimate, with a small output, and only primitive facilities. When the narrow-gauge railway from Covadonga to Rivadesella is in working order, he thinks a further reduction of about 7s. per ton may be effected.

Table IV. gives the average of five analyses of Asturiana ores as given by Mr. Jones, compared with those obtained by me. It will be seen they agree very nearly with my figures, and leave no room for doubt as to the high quality of the ore:—

TABLE IV.

	Asturiana Ores as per Mr. Jones' Paper. Analyst not stated.	The same as made for me by Pattison and Stead.
	Per Cent.	Per Cent.
Manganese (Mn)	58·26	58·35
Iron (Fe)	1·42	1·10
Silica (SiO_2)	1·66	0·90
Phosphorus (P)	0·016	0·01
Copper (Cu)	..	trace
Water (H_2O)	1·33	...

Mr. Jones thinks the ore may be classed as follows:—

	Per Cent.
Crystalline ($2Mn_2O$, MnO)	40
Crypto-crystalline ($2Mn_2O$, MnO)	45
Pyrolusite (MnO_2)	15
	100

Taking the market value of the ore delivered at a British port at the present price of 1s. 1d. per unit, or £2, 15s. 3d. per ton for 51 units (*i.e.*, containing 51 per cent. of manganese), which is perhaps as much as whole cargoes can be expected to yield, it would appear that the handsome profit of 17s. 7½d. per ton may be expected under the proposed new conditions, and without the benefit of railway transit from Covadonga to Rivadesella.

Already a cargo of 200 tons has reached a British port since the Asturiana Limited commenced operations. This cargo actually yielded an average of 60 per cent. of manganese, and 0·014 only of phosphorus. There is every probability of an early and quick development not only of their mines, but also of the adjoining concession, and possibly of those at the Arenas end of the vein. If these expectations should be justified by results, the European steel trade, as well as Spanish mining industry, will be greatly benefited.

A few words as to the competition which will have to be faced by the manganese mine-owners of Northern Spain may not be without interest.

The usual sources of supply of manganese ore to the British market are as follows :—

The Caucasus, the Levant, the French Pyrenees, Spain, Brazil, Chili, India, and Japan. It has also been found in New Zealand, Cuba, Central America, Portugal, Sardinia, Corinth, Germany, and Merionethshire, but none of these last-named sources seem so far to place any great quantity of high-class ore on the market.

Of the Cuban deposit Mr. E. J. Chibas, writing in the American *Polytechnic*, says :—

"The ore is found near the south-eastern extremity of the island. Here is a range of mountains, the highest peak of which is 7670 feet above sea-level, which becomes broken into a number of smaller ranges. At the summits, or on the flanks of these, the manganese ore is usually found. Sometimes it is wholly in rock, whilst at others it lies in pockets irregularly distributed over many acres of clay, representing the decomposition of the ore-bearing rock. The pockets are usually covered by about a foot of soil, and their number and extent is therefore unknown.

An average analysis of several cargoes was as follows:—

	Per Cent.
Manganese	47 to 53
Silica	4 to 9
Phosphorus	0·03 to 0·10

One particular cargo from the Gloria mine gave as much as 55·21 per cent. of manganese.

The most extensive deposits are twelve miles from the Christo railway station. Here with a pick and shovel a man can extract between three and four tons of ore per day. The ore is placed in bags containing 100 lbs. each, and carried (in pairs) to the railway station on mules.

The cost delivered to Philadelphia is:—

	Per Ton. £	s.	d.
Extraction	0	11	3
Transport to railway	0	18	9
„ Philadelphia	1	2	6
Total	2	12	6

The circumstances in this case seem to resemble closely those of the Spanish deposits.

At the present time the Cuban mines are entirely inoperative on account of the insurrection.

With respect to the United States, manganiferous ores are found in Virginia, North Carolina, Georgia, Arkansas, Colorado, Lower California, New Mexico, Arizona, and Texas. Most of these deposits are of a low-grade kind. The Carnegie Company of Pittsburg are now the only makers of ferro-manganese in America. Their consumption of ore is about 60,000 tons per annum. Delivered at Pittsburg, 1s. 2d. to 1s. 4d. per unit can be obtained for ore containing from 40 to 50 per cent. of manganese, and not above 0·1 per cent. of phosphorus and 8 per cent. of silica.

In Canada a deposit of high-grade ore containing 95 per cent. of manganese-dioxide (MnO_2) and no iron, and situated near Windsor, Nova Scotia, has been worked fitfully for the past thirty-five years. The cost of mining and delivery to Halifax, 150 miles distant, has been too great for commercial success, and the mine is now closed. The average annual production did not exceed 100 tons.

An exceedingly promising source of manganese ore has recently been discovered at a point 5½ miles from the port of Hillsborough, New Brunswick. This ore, which is of the variety known as "wad" or "bog" ore, has the following analysis:—

Average of Twelve Samples dried at 212°.

	Per Cent.
Manganese-dioxide (MnO_2)	72·56
Ferric oxide (Fe_2O_3)	14·21
Sulphur (S)	0·03
Phosphorus (P)	0·05
Silica (SiO_2)	5·36
Other constituents (by difference)	7·79
	100·00
Metallic manganese	45·81

If we assume that the only remaining ingredients are water of hydration and carbonaceous matter, this is a remarkably pure ore. It lies in a homogeneous deposit which in places is as much as 30 feet thick. It has apparently been produced by the aqueous solution of manganiferous rocks at a higher level and subsequent precipitation on loss of carbonic-dioxide. Being in a pulverised condition, it requires forming into briquettes before smelting. Mr. Edison of Menloe Park, New York, has recently given his attention to this matter with considerable success. On the table is a specimen of the ore in its original condition, and another of it when made into briquettes. Mr. Edison's method is to mix the ore with crude petroleum to the extent of 2 per cent., and then to consolidate with a pressure of 24 tons per square inch. Each of his machines is capable of producing 15 cwt. per hour.

Owing to the granular condition of this ore, and the fact that the deposit is within two inches of the surface, it can be worked with the steam navvy, thus reducing the cost of getting to a minimum. The quantity available seems to be very large, and there is little doubt it could be put f.o.b. at Hillsborough for 5s. per ton, or delivered to Pittsburg, or a British port, in quantity for about £1, 10s. per ton, or say 8d. per unit. Inasmuch as Cape Breton coal may be had at Hillsborough for 8s. per ton, the mineral might preferably be smelted there. The Canadian Government gives at present a bounty on all pig iron or similar

products smelted in the dominion from native ores. This would be an extra inducement to export the finished rather than the raw product.

As a rule, manganese ore is found in veins and pockets in rock of both igneous and sedimentary origin. The deposits are usually very irregular and unreliable. Above water-level the ore is generally in the condition of black oxide (MnO_2); below it is usually carbonate ($MnCO_3$), or silicate ($MnSiO_3$). The veins have been proved to depths varying from 50 to 300 feet, the quantity and quality diminishing with the depth. The veins are not as a rule main fissure veins, but of a more superficial character, and filling rock joints. Iron and manganese are almost always associated, ferric oxide (Fe_2O_3) replacing manganese-dioxide (MnO_2) at the greater depths.*

In conclusion, I desire to acknowledge the very valuable assistance I have received from Mr. R. E. Stone, Mr. R. Everitt, Mr. Scoby Smith, and from Mr. A. P. Head, who made the map and photographs which illustrate this paper, except in the case of two (46 and 49), which are copied from the statement of the Asturiana Company.

* *Transactions of the Federated Institution of Mining Engineers*, vol. iv. p. 167.

DISCUSSION.

Mr. Bauerman was glad that Mr. Head had brought this interesting district before the members. He might mention as a matter of history that he had himself investigated the country a good many years ago, before the workings referred to in the paper had been made. From what he saw then he concluded that the so-called filon or vein was a series of open fissures in the limestone which had been filled from above, much in the same manner as the fissures containing the paint ores of the Mendip Hills. Where the rock had been divided into hollows, the so-called "bolsas," or purses, were found containing nodular accumulations of rich ore, which were partly, but not entirely, products of the waste of the vein above; at any rate, some of them appeared to have a concretionary structure as though they had originated on the spot; determinations which, though not showing any relation to the mechanical properties of steel, would be a useful addition to their knowledge of the subject.

CORRESPONDENCE.

Mr. H. G. Turner noted that India was one of the sources of supply of manganese ore mentioned in Mr. Head's paper. It was, however, only recently that India had sent manganese ore to Europe and also to the United States, and some account of the deposits now being worked in India, and of the trade, might be of interest to the members of the Iron and Steel Institute.

About five years ago attention was directed to a small deposit of this ore in the Vizagapatam District of the Madras Presidency, and further exploration brought to light the occurrence of the mineral in large quantities throughout a considerable extent of country. The ore outcropped in various places over, so far as was known, an area of 100 square miles, situated within the extensive territories of H.H. The Maharajah of Vizianagram, a well-known and distinguished Hindu nobleman. Topographically, the manganiferous area was part of the littoral tract of country

which stretched between the range of mountains known as the Eastern Ghats and the Bay of Bengal. It was somewhere about 500 miles north of the city of Madras, and about the same distance south of Calcutta. The East Coast Railway passed over the area, and two good roadsteads were within 40 and 60 miles respectively. Vizagapatam, the latter port, was touched by the railway, and all the ore exported was sent by rail to, and shipped from, that port. Unlike many manganese deposits in other parts of the world, these Indian deposits of ore occurred not in a mountainous tract, but in a plain country, through which the railway passed on a gradient which rose but little above sea-level. The country being densely populated, every cultivable acre was under the plough. Agriculture was the only industry, and there was a large surplus population from which abundance of labour was procurable in all months of the year. Even in tilling time (in June and July) and in harvest (December and part of January), when the supply of coolies diminished, there were always sufficient hands to keep the mines going. The climate was perfectly healthy throughout the year, and suitable for Europeans. From February to June it was exceedingly hot, with now and then a thunderstorm. The thermometer fell considerably at night, and the locality being so near the sea, the excessive heat was tempered by sea-breezes. The south-west monsoon came in June, and the north-east in October. During these periods the rainfall was heavy, sometimes continuing for several days. Intervals of fine weather were frequent. The average annual rainfall was about 40 inches.

The outcrops of manganese ore occurred in the form of mounds, as low hills, and in isolated blocks, while in some places the soil, impregnated with black oxide of manganese, gave indications of ore beneath the surface. The first mound discovered was within a few hundred yards of the railway. Unaware of its nature and value, the railway contractors were breaking up the boulders of manganese rock for ballast. This mound consisted of about 60 acres of black manganese rock and boulders intermixed with an alluvium of decomposed gneiss.

Further investigation showed that this mound was the butt-end of a deposit of vein-like masses of ore and detached boulders imbedded in detritus of country rock. This deposit being about

$2\frac{1}{2}$ miles in length, comprises an area of 660 acres. There was probably a spine of hard ore all along this length, or perhaps the remains of a spine. The detached blocks of ore exhibited marks of being water-worn, and these occur in all sizes, from a pebble up to great boulders of several hundredweight. These broken fragments were disseminated throughout the soil, sometimes so sparsely as to make quarrying unprofitable, at other places in drifts and beds several feet thick, and of value.'

The nodules were coated with a thin layer of oxide of iron, and when broken presented a steel-grey colour. They contained from 45 per cent. to 48 per cent. of metallic manganese. Other nodules were angular, and when fractured showed a metallic lustre. These were richer in composition than the first-named, containing 48 per cent. to 50 per cent. metallic manganese. The vein-like masses had been worked to a depth of 50 feet. The ore in these veins varied very considerably in manganese, in iron, and in phosphorus. Some was of a steel-grey colour, with 48 per cent. manganese, and associated with it was a cindery ore of 35 per cent. Another variety was porous. The occurrence of phosphorus in these quite adjacent veins was peculiar. Two varieties presenting perfectly similar external appearance might contain, the one 0·1 per cent. of phosphorus, the other 0·2 per cent.

Further along the deposit, ore occurred of equally variable nature. A very fine deposit of soft blue pyrolusite was being worked at the extreme end of the property. This ore was of good quality, yielding, after selection, about 80 per cent. of peroxide, while the impure variety yielded about 70 per cent. There were several outcrops of manganiferous iron ore, which yielded on an average 41·17 per cent. of manganese, 0·166 per cent. of phosphorus, and 17·9 per cent. of iron. There still remained a very large unexplored area lying within the boundaries of this deposit.

During the current year some 30,000 tons of ore had been sold and was being shipped from this mine by the Vizianagram Mining Company, to which it belonged. The high class ore went to the ferro-manganese makers, and the lower class to the basic furnaces, while the pyrolusite was taken by chemical works.

Recently other deposits had been discovered, notably one at a village called Garbham, some ten miles from the Kodur mine. An

experienced engineer from a well-known London firm had visited this deposit. He reported that it probably contained 1,500,000 tons of ore down to water-level, *i.e.*, above the water-level of the country. This deposit consisted of a mass of ore some 80 feet high, half a mile long, and 100 yards wide, with two small outliers. Works were being started in this remarkable hill. The whole mass appeared to consist of great slabs of manganese, which, when blasted, yielded ore of various quality. Shipments were being made of this ore, based on samples which had been approved by brokers and consumers. It was proposed to lay down a mineral tramway line to facilitate the transport of this ore to the railway. The Vizianagram Mining Company were in treaty for the purchase of this property.

Throughout the manganiferous area labour was plentiful and cheap. Bullock carts were abundant, though some difficulty was experienced in getting large numbers of carts for a few weeks in the season of cultivation. The Kodur property had some tram lines, and more would be provided; Garbham would also be properly equipped in this respect. Extraction of ore was carried on principally by contract, and the work was very much sought after by the country people, who had unbounded confidence in the good faith of Mr. Eunson, the head of the works, who was recently described to a visiting director by an English-speaking native as being a "very justice gentleman."

The industry was fairly established, but this had not been accomplished without trials of disappointment and perseverance. To Mr. Eunson, who had been persistent in his hope of ultimate success, the industry was much indebted. Nor had it been easy to establish markets for the ore. However, these difficulties were now disappearing, and it was a source of much gratification to all concerned to find that this year 30,000 tons of ore had been sold, and more could have been put in the market if the new deposit had been properly equipped.

Freights also caused trouble at first, and the novelty of the cargo, coupled with distrust of the shipping capabilities of the port, had to be overcome before satisfactory arrangements could be made. The nearest port to the mines was Bimlipatam, but hitherto the Government had, for various reasons, which were being combated, declined to construct a branch line to that

place. It was a better port than Vizagapatam, to which the ore was now being railed. If this branch line was made, facilities for exporting very large quantities of ore would at once ensue. It was hoped that the creation of a new trade would induce the Government of India to take a favourable view of the situation.

During the last five years great attention had been paid to ascertain, and to become familiar with, the chemical characteristics of the ore. More than 500 analyses of it had been made by Mr. Dains, the able chemist employed on the works by the Vizianagram Mining Company, and, as a matter of course, samples of every cargo had been analysed by the brokers and by the purchasers.

The constituents of the ore varied very considerably, and it required great experience, and great intelligence, to discern by sight, even after chemical analysis, to what class any new deposit belonged. The classification of the ore destined for the furnaces was determined by the phosphorus it contained. Ore was admitted as first class if not above 0·15 per cent. in phosphorus, while ore containing more phosphorus was classed in the second grade.

The general character of the ore was hard, compact, and well suited for use in the blast-furnace. The mechanical condition of the rich ore, coupled with its very low contents of silica, admitted of its being mixed to advantage with the lower phosphoretted ores from Brazil and Chili. Thus, the blending of the Indian phosphatic ores, free from silica, with the ores supplied from other sources, enabled the furnace masters to effect an economy in the cost of the burthen varying from 5 to 10 per cent. An additional economy arose from the fact that the Indian mineral carried sufficient iron for the manufacture of ordinary qualities of ferro-manganese, thus avoiding the necessity of purchasing additional iron ore. Although, therefore, the Indian ore was not so rich in manganese, and contained more phosphorus than the Brazil and Chili ores, its behaviour in the furnace left nothing to be desired. It was comparatively free from silica (averaging about 3 per cent.), and was essentially a manganiferous mineral. It existed in enormous quantities, and was cheap to work, to rail, and to ship. Considerable progress was to be observed in the demand for the ore, and there was every probability of a large

and valuable trade being established within a short period of time.

It was somewhat curious, though it may be only a coincidence, that Josiah Marshall Heath, one of the earliest adopters of the use of manganese in the manufacture of steel, was a civilian on the Madras Establishment in the early part of the century, and he abandoned the career of the Indian Civil Service to take up the development of the iron industry in South India. It was true that the scene of his labours was a long way south of Vizagapatam, and of the manganese mines now being worked. There was no record of his ever having known of the existence of the deposits; but these ores were nevertheless known and worked by the native smelters, as vestiges of the furnaces were still to be seen close to the Garbham Hill. Whether Heath's mind was directed to the process which he introduced at Sheffield, and which led to his unmerited ruin, by knowledge derived from any Indian source, is a curious point, which is deserving of notice if any one comes across information on the subject. Mr. Turner gave the following typical analyses of ore sold to various consumers in England, on the Continent, and in America:—

	I.	II.	III.	IV.	V.
Moisture	1·10	1·30	1·65	1·80	1·48
Manganese	48·65	46·15	50·35	45·08	47·09
Iron	7·10	10·35	6·38	13·23	10·80
Phosphorus	0·12	0·21	0·24	0·27	0·26
Silica	2·23	3·20	3·21	4·60	2·45

Note.—I. Kodur ore; II. Kodur ore; III. Garbham ore; IV. Garbham ore; V. Garbham ore (cargo test).

After a cordial vote of thanks to Mr. Head for his paper had been proposed by the President, the following paper was read:—

A NOTE ON THE PRESENCE OF FIXED NITROGEN IN STEEL.

By F. W. HARBORD, Assoc. R.S.M., F.I.C.,
AND
T. TWYNAM, Royal Indian Engineering College, Cooper's Hill.

THAT nitrogen exists in steel in a state of combination has long been recognised by metallurgists, and further, that iron specially nitrogenised by the action of ammonia is materially altered in character is also well known. Although these facts have long been published, we believe that since the paper read by Mr. Allen on the subject before this Institute in 1880, hardly any results have appeared, although no doubt numerous determinations must have been made.

The early workers in this field were Frémy and Boussingault on the Continent, and A. H. Allen in this country, who, in the paper above referred to, gives full details of by far the most ready and accurate method of determining this element as it exists in steel, and is substantially the one that has been used throughout for our determinations.

Nitrogen undoubtedly exists in steel in two conditions, as on solution of the steel in a suitable solvent, or by boring under water or mercury, a far larger amount of nitrogen is obtained than can be found when the fixed nitrogen only is estimated. It appears probable that this nitrogen is merely mechanically occluded in the metal, whilst the fixed nitrogen undoubtedly exists in combination with some other element present, either iron, manganese, or carbon, but probably the former.

The authors in the course of their work have had from time to time to examine samples of steel which have failed under varying conditions, and in which, in some cases, neither the usual analytical nor the mechanical tests have in any way indicated the cause of failure. In some of these cases they have thought it of interest to determine the amount of fixed nitrogen present, and although they have failed to trace any connection between

the amount of nitrogen and the good or bad quality of the steel, yet, in view of the small number of published analyses in which the fixed nitrogen is given, the results they have obtained may be of some slight interest.

In the course of an investigation, referred to in the paper, the authors determined the combined nitrogen in a number of steels made by most of the well-known processes, but their results appear only to confirm the generally accepted opinion that nitrogen, in the proportion in which it is found in commercial steel, has no detrimental effect.

For convenience they have classified the steels under their various methods of manufacture, the results being as follows:—

Bessemer Steel.

	Rails which Broke in Use.		Normal Rails.				
	A.	B.	C.	D.	E.	F.	G.
Carbon	0·458	0·462	0·377	0·360	0·354	0·335	0·376
Silicon	0·196	0·112	0·046	0·024	0·028	0·026	0·004
Sulphur	0·055	0·088	0·052	0·038	0·047	0·050	0·055
Phosphorus	0·099	0·078	0·061	0·030	0·030	0·049	0·049
Manganese	1·480	0·450	0·367	1·150	1·128	0·500	0·990
Arsenic	...	0·036	0·033	0·012	0·009	0·016	0·016
Nitrogen	0·027	0·017	0·017	0·011	0·007	0·012	0·015

In Sample A the analysis is sufficient to explain the failure, but apart from this there was a large flaw extending nearly through the head of the rail, and the analysis given represents the composition of the steel close to the flaw.

In Sample B neither the analysis nor the tensile tests were such as to account for the fracture, and the fixed nitrogen throws no light on the matter. Sample C was a rail which had stood for very many years under an exceptionally heavy traffic, and which was in good condition when removed. The other samples, D, E, F, and G, are simply given as showing the percentage of nitrogen in ordinary rail steel.

Siemens Steel.

	Samples that Failed in Use.				Normal Axle.
	Tires.		Axles.		
Carbon	0·297	0·302	0·183	0·258	0·220
Silicon	0·057	0·056	0·034	0·028	0·036
Sulphur	0·102	0·102	0·074	0·053	0·026
Phosphorus	0·054	0·055	0·049	0·045	0·029
Manganese	0·875	0·900	0·950	0·750	0·550
Arsenic	0·027	0·029	0·035	0·027	0·007
Nitrogen	0·021	0·023	0·019	0·019	0·011

Swedish Bessemer Steel.

We were recently asked to examine two samples of solid-drawn tube made from undoubted Swedish steel; one of these (A) had drawn out perfectly, whilst the other (B) had developed a multitude of small cracks over the surface. As both tubes gave good analytical results, the authors thought that possibly in the bad tube they would find an increase in the percentage of fixed nitrogen, which in such a case might be looked upon as an indication of over-blowing. Such, however, was not the case, as the following results show :—

	A. Good Tube.	B. Bad Tube.
Carbon	0·259	0·200
Silicon	0·018	0·014
Sulphur	0·006	0·006
Phosphorus	0·027	0·042
Manganese	0·193	0·199
Arsenic	0·015	0·013
Nitrogen	0·024	0·016

It is of interest to note that in the above cases the blows were stopped when the desired percentage of carbon was reached, and no additions of ferro were made.

Crucible Steel.

The following analyses of springs are quoted :—

Carbon	1·050	1·000	1·120
Silicon	0·034	0·066	0·093
Sulphur	0·038	0·030	0·027
Phosphorus	0·053	0·042	0·029
Manganese	0·468	0·618	0·550
Arsenic	0·009	0·014	0·012
Nitrogen	0·007	0·009	0·007

It has recently been shown by O. Prelinger * that manganese forms, when heated in nitrogen gas, a well-defined nitride, Mn_5N_2, stable at a red heat, and in view of this fact it occurred to the authors that possibly the still unexplained beneficial action of manganese in the steel might be due to some extent to the formation of a nitride of manganese, and it was to see if the nitrogen increased with the percentage of manganese that some of the above analyses were made. In three steels, two of which are high and one fairly low in manganese, it will be seen that, if anything, the nitrogen was higher in the steel with the lower manganese:—

Carbon	0·360	0·354	0·335
Manganese	1·150	1·128	0·500
Nitrogen	0·011	0·007	0·012

The authors then made a series of analyses on metal taken from three charges of basic Bessemer steel, and from one basic Siemens charge, with the object of seeing whether any notable change could be found in the fixed nitrogen in samples taken before and after the addition of ferro-manganese. A sample was also taken about three minutes from the commencement of the afterblow. The results are given below, 1 being sample at three minutes afterblow, 2 being the blowers' finished sample, and 3 the steel after addition of ferro:—

	1.	2.	3.	1.	2.	3.	1.	2.	3.
Carbon	0·017	0·017	0·100	0·025	0·032	0·110	0·032	0·037	0·110
Silicon	trace	trace	trace	trace	trace	trace	trace	trace	trace
Sulphur	0·080	0·047	0·048	0·120	0·063	0 060	0·109	0·057	0·057
Phosphorus	0·760	0·040	0·050	0·880	0·060	0·075	0·780	0·052	0·070
Manganese	0·080	0·120	0·450	0·100	0·150	0·420	0·120	0·130	0·375
Nitrogen	0·009	0·011	0·017	0·010	0·011	0·012	0·010	0·017	0·017

Although these figures show no appreciable change in the actual percentage of fixed nitrogen, it is, of course, possible that manganese may replace iron in the nitride present in the blown metal, a point difficult to decide by direct experiment, and one the authors are still investigating.

* *Monatshefte für Chemie*, vol. xv. pp. 391–401.

The samples from the basic Siemens charge gave the following results:—

	Before Tapping.	Finished Steel after Addition of Ferro.
Carbon	0·060	0·085
Silicon	0·006	0·008
Sulphur	0·019	0·018
Phosphorus	0·025	0·028
Manganese	0·188	0·450
Nitrogen	0·006	0·006

The original intention of the authors was not to publish these results, except in so far as they might throw light upon the presence of nitride of manganese in steel; and they now somewhat hesitate to bring them forward, especially as they do not admit of any definite conclusions being drawn. In view, however, of the few published analyses of steel showing the percentage of combined nitrogen, and the well-known detrimental effect of this element when artificially combined with iron, they thought this short note might direct renewed attention to the subject.

DISCUSSION.

Dr. WEDDING said that Professor Rammelsberg of Berlin had formerly made numerous experiments regarding nitrogen in different sorts of iron, pig, steel, and wrought iron.

Mr. J. E. STEAD, member of Council, said it was interesting to have records like those given by Mr. Harbord, and complimented him on the work he had done. Without taking exception to anything that Mr. Harbord had said, he might be permitted to call attention to the interesting work of Mr. Hogg of Messrs. Spencer & Sons at Newburn. After dissolving ferro-manganese in acid, he had found the residue loaded with very perfect crystals of nitrocyanide of titanium. He thought Mr. Harbord would not get nitrogen with such material by his method; it would remain insoluble as little crystals. The compound was the same as that found in blast-furnace bears.

Dr. S. RIDEAL regretted that Professor Roberts-Austen was not present. When last year attention was called to a paper read at the Royal Society on argon, Professor Roberts-Austen suggested the possibility of argon recurring in steels, and its relation to the large volume of air blown through in a Bessemer converter. He should like to ask Mr. Harbord whether his analysis showed any relation between the nitrogen and the volume of air passed through into the steel?

Mr. HARBORD said he was aware that a good many determinations had been made with reference to nitrogen in wrought iron and steel, but he believed that practically no results had been published, expect those by Allen showing the percentage of nitrogen in different varieties of steel. With regard to Mr. Stead's remark, he had hoped to have made a determination of nitrogen in Hadfield's manganese steel, but he had not been able to get a sample in time. In all probability any nitrogen present as nitro-cyanide of titanium in ferro referred to would not be determined by the method employed. He had not gone into the question of argon in steel, but as far as the amount of com-

bined nitrogen in steel was concerned, it appeared to bear no relation whatever to the volume of air blown through, as no practical difference was found between the amount of nitrogen in Bessemer or open-hearth steel, although in the case of crucible steel nitrogen was distinctly lower than in either Bessemer or open-hearth steel. He believed, however, that Mr. Saniter had made experiments on those lines, and had actually discovered some argon in Bessemer steel, to which he had referred in the discussion on a paper read before the Institute last year.

CORRESPONDENCE.

Mr. E. H. SANITER thought that it was of interest to note that of all the steels tested for nitrogen by Messrs. Harbord and Twynam, that from the basic Siemens furnace was the lowest. Might not this have some connection with the great ductility of this steel?

On the motion of the President a vote of thanks was passed to Mr. Harbord for his paper, and the meeting was adjourned.

The proceedings were resumed on September 2nd—Sir DAVID DALE, President, again occupying the chair. The following paper was the first to be read:—

SAND ON PIG IRON AND ITS AVOIDANCE.

By HENRY D. HIBBARD (High Bridge, New Jersey).

If any apology or reason is needed for presenting a paper on this subject, it is to be found in the continually increasing demand for sand-free pig iron for the basic open-hearth steel process, and in the numerous plans proposed and tried for reducing labour in the production of pig iron, some of which have the avoidance of silica on the pig as a secondary aim.

The question was urged upon the writer's attention several years ago by the difficulty of obtaining a supply of suitable pig iron for use in the basic open-hearth steel furnace. In the consideration of the matter the apparatus for casting pig iron described in this paper was devised, and it became evident that a great reduction of labour about the blast-furnace could be effected by the use of a mechanical casting appliance, and also that sand-free pig would be desirable in other lines of consumption.

Labour-saving devices have hitherto covered the whole field of operations involved in the production of steel from ore with the exception of casting and handling pig iron, and this may now be done, and the iron kept free from sand at the same time.

As is well known, sand is, chemically speaking, chiefly silica. Let us consider its behaviour and treatment in the following lines of consumption, taking up the question from the producers' side later :—

(1.) The Basic Open-Hearth Process.
(2.) The Bessemer Process.
(3.) The Puddling Process.
(4.) The Foundry.
(5.) In General.

1. *The Basic Open-Hearth Process.*—In the operation of this process the most troublesome and destructive agent met with is silica in the furnace. It causes trouble by cutting and destroying the bottom, and by preventing, or at least retarding, the removal

of phosphorus from the metal when present in considerable quantities. It is introduced in the form of sand sticking to the pigs from the sandbed in which they were cast, and is also formed in the furnace by the oxidation of the combined silicon in the iron. Experience shows, however, that the evil effects of the latter, especially in cutting the bottom, are not nearly as marked as in the case of the sand on the pigs. Most of the combined silicon is oxidised to silica after the charge is melted, when the bottom is not exposed to the action of the slag except along the slag-line at the surface of the bath. In the slag itself, where the silica is all collected, it is diluted by the excess of basic material, and its corrosive effect practically neutralised. The sand on the pigs, on the other hand, begins the destruction of the bottom as soon as brought in contact with it at a sufficiently high temperature, which is early in the history of the heat. The motto of the basic open-hearth steel melter should be, "Beware of silica." With great relief he would miss the one to three per cent. of sand commonly found on commercial pig iron, were it only absent.

If those experienced in this process claim that they can work successfully with common sand pig iron, then it may be said that by using clean pig iron the limit of combined silicon permissible in the iron is raised so as to include nearly all grey iron made, as far as that is concerned, and the special manufacture of basic pig iron will be reduced to the one condition of casting common grey foundry or mill iron in clean iron moulds. This will do away with the trouble from high sulphur in the low silicon pig iron now especially made for basic open-hearth work, and will also render useless the one and a half per cent. of manganese sometimes put in basic pig iron with the especial object of the removal of sulphur in the blast-furnace. This manganese is practically all wasted in working the process.

To avoid the sand and silicon difficulty by blowing the metal in an acid-lined Bessemer converter, after melting in a cupola, may be effective, but it is expensive and useless. The increased output can be more than met by putting the cost of the Bessemer plant into additional melting furnaces. The operations of the plant would then be simpler, and the different parts more independent of each other.

In the acid open-hearth process, a little sand is sometimes a

good thing to introduce to satisfy chemically the basic oxide of iron inevitably formed in melting scrap. Still it need not be paid for at pig-iron prices.

2. *The Bessemer Process.*—In the Bessemer process, both acid and basic, the sand is removed from the pig iron when it is melted in the cupola, and for this reason causes no trouble during conversion proper. But in the cupola it calls for increased consumption of limestone, and the slag caused by the two ingredients carries off some 15 per cent. of iron, and must also be melted, causing extra consumption of coke, while the cupola lining suffers from the eroding action of the slag. Further, the slag must be disposed of after it has left the cupola. Each of these items costs money.

3. *The Puddling Process.*—In the puddling or boiling process, which is commonly, if not universally practised as a basic process, the presence of silica in the furnace is very undesirable. It cuts and wastes the fix, and hinders the elimination of the phosphorus, thus lowering the quality of the iron produced. By using iron free from sand, less ore and fix are consumed per ton of product, and as a result, fuel and time are cut down and the quality improved.

4. *The Foundry.*—In foundry practice sand-free pig iron is desirable for the same reasons as in the Bessemer process. To one familiar with them, fractures of iron cast in chills give an accurate idea of their relative hardness, which can by no means be said of sand pig iron, in which the grain is influenced by the rate of cooling, usually checked as much as possible by a liberal application of sand. Of course, the fracture will apparently show the iron to be very much harder than if cast in sand if the observer is unacquainted with the fractures of irons cast in chills, but a little experience will teach what to expect in the castings from a given fracture of the pig iron, and the foundryman would soon be better off in this respect than he is now. Re-melting puts the iron in a normal condition. The percentage of the chemical elements which enter into its composition, and on which its adaptability to its use depends, are unchanged.

5. *General.*—In general the consumer buys a lot of worse than worthless sand instead of iron. The allowance of 1¼ per cent. now made does not nearly cover it, though if made large enough to do so the case would only be half cured. Some blast-

furnace managers seem to seek the varieties of sand (not to say gravel) which will stick most abundantly to the pig iron, and the amount they get on sometimes exceeds 3 per cent.* This amount, over 1¼ per cent., is sold as iron, and is present to cause trouble and expense to the consumer at every turn.

The cost of getting the sand to the cast-house borne by the blast-furnace is exceeded by that of handling and disposing of it and its products afterward borne by the consumer.

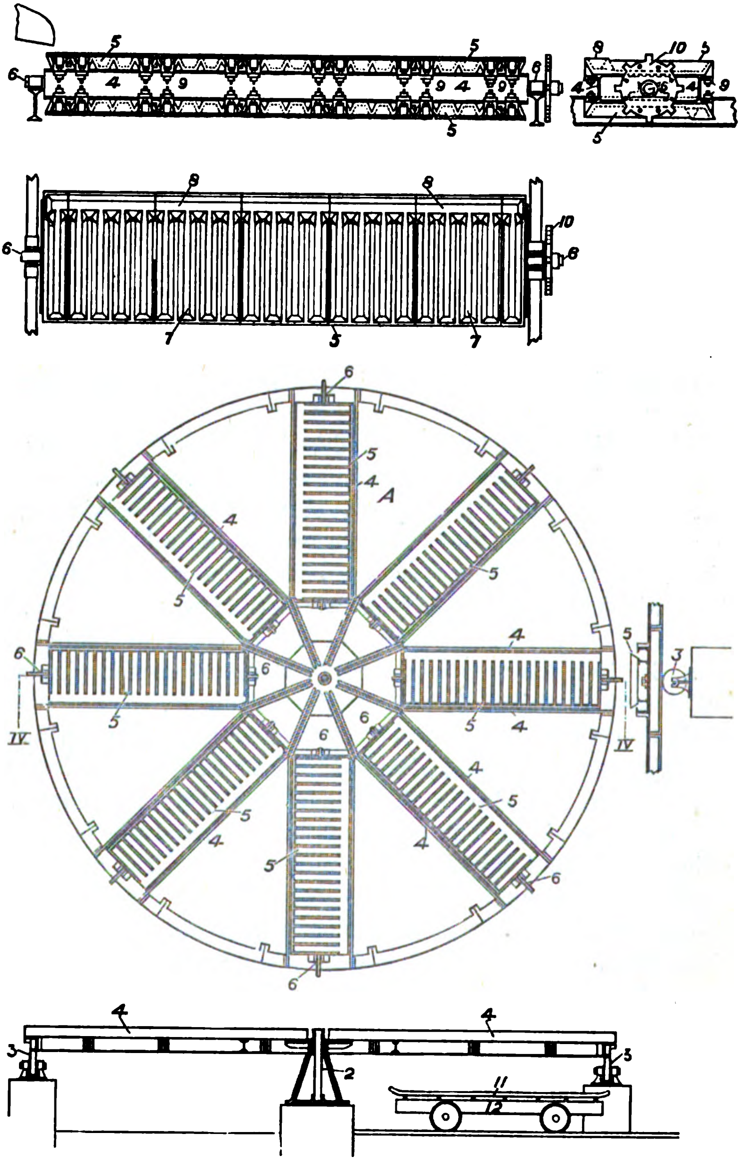
Pig iron cast in ordinary stationary chills is only half cured of sand, as the chills always have quite a lot of sand in them before running in the iron. Only tipping-moulds or an equivalent will ensure clean pig free from sand. From them everything is tipped out.

In 1895 the United States produced some 9,500,000 tons of pig iron, probably carrying on an average 1 per cent. of sand above the allowance. If only that 1 per cent. was paid for, it means that 95,000 tons of sand were bought and sold at the price of iron, say 12·00 dollars per ton. This amounts to 1,140,000 dollars which consumers paid for worse than worthless sand, to say nothing of the large amount of money spent in getting rid of it. In fact, the whole expense of the sand on the pigs, say 213,750 tons, is ultimately paid by the consumers.

It is thought that producers of pig iron will find this apparatus for casting pig interesting, because of the saving it strives to effect in plant, and also in the labour of casting and handling pig iron. The pigs are not touched by hand, and the labour of making up the sand-pig beds is entirely avoided. One cast-house only is required for a whole furnace plant, and consequently the cast-house now found at each furnace may be dispensed with.

The great saving comes, however, from doing away with labour. It is estimated that two crews of ten or twelve men each can cast, cool, and ship 1000 tons per twenty-four hours with one turntable. More than this would require additional tables. The operation of the turntable and tipping-moulds is simple, and readily understood by reference to the accompanying illustrations.

* Since writing the above I have heard of a case where the chemist of a great iron-producing firm was commissioned to find a sand which would stick in the largest possible proportion to pig iron. He did it. Another steelworks' manager assures me that at the blast-furnaces connected with their works they used to get over 4 per cent. of sand on their pig iron.



APPARATUS FOR CASTING PIG IRON.

The apparatus consists of a frame mounted on a vertical pivot (2), and supported by anti-friction wheels (3). Between each pair of beams (4, 4), is a series of moulds (5), which may be tipped by trunnions (6). The rotatory table may be replaced by stationary supports. The moulds then consist of a casting with cross cavities (7), connected by a longitudinal cavity (8). They may be made in sections, secured together by bolts (9). A wheel (10) is applied to one of the trunnions for tipping the moulds.

The iron is run from the blast-furnace into 20-ton ladles, which are hauled to the cast-house, and cast in succession. The moulds, corresponding to the ordinary pig beds, are mounted in series on pivoted frames. Each of these frames carries two or more series, so that when the moulds are empty they balance each other, and there is no tendency for the frame to turn on the pivots. But when the top mould series is filled the frame is top-heavy, and so will, when permitted, turn over, and discharge the pigs on the truck standing below.

These frames carrying the moulds are mounted radially in a turntable which revolves, and so brings the mould series successively into position for filling. They are filled on one side, and tipped on the other side of the house when the table has made half a revolution. On tipping, a cold series of moulds is brought to the top ready for filling. The pigs are tipped while still red-hot, and, striking suitable projections on the truck, are for the most part broken from the sow by the fall, which also breaks the sow into pieces; but men must be ready with sledge and bar to supplement such action in case some still remain not broken off.

The surely to come great extension of the basic open-hearth process in the near future will give a large market for suitable pig, and furnaces which first equip themselves to supply this demand will have a great advantage over others, and their iron will command a premium. The introduction of sand-free pig in other lines will perhaps be less urgent, but still desirable; and the disappearance, in large measure, of sand pig from the market may be expected. By separating the furnace and cast-house, parcels of land formerly unsuitable become available for furnace plants, as the furnace and cast-house may be at some distance from each other.

The proposed methods of making pig iron free from silica, by casting it in a bed of ore or roll-scale, are not feasible. The expense will be greater than now, and the cure only half effected, as siliceous material is carried about on the feet of the workmen, blown in from without by the wind, and out of the furnace by the blast—the slag being siliceous. Labour in this case will not be lessened at all. Further oxide of iron sticking to the pig would tend to unfit it for some purposes, notably in the foundry,

where it will, by oxidising the silicon in the cupola, make the iron harder. The pig iron output of blast-furnaces and yield of the ores may apparently, but not actually, be cut down when the usual daily tons of sand are not weighed up as iron. Producers of pig iron who consume their own product have not the advantage of selling sand for iron. The sand to them is simply an expense, both before and after it is stuck to the pig.

From the foregoing, consumers may be able to estimate for themselves the advantage they would have, could they obtain a supply of sand-free pig. At the end of this paper will be found an estimate of the saving to be effected by the use of turntables, which is thought to be well within limits.

The cost of making iron moulds for the turntable is not great with ladles of molten iron constantly at hand. It will only be that of moulding, the broken moulds being available for use as pig iron. With a good mechanical system of casting, less scrap and fins will be made. The small pieces of iron are lost in transit, or buried beneath accumulations of sand in the metal yard. For cooling the metal after being cast, air is of course the cheapest agent, but, it being rather slow, water when cheaply furnished is preferable, because of the time it saves. It also reduces the number of cars and track room needed.

Probably the iron from each ladle will be found to be more uniform in composition than is usual in the metal as it flows from the furnace. This if so will greatly facilitate sampling, as only one pig need be broken, or sample be taken for analysis. Each ladle of 20 tons of iron would naturally make a truck-load. At the time it is filled from the furnace, the metal would be fairly homogeneous, and though there would be some stratification on standing, it would be easy to take a sample from each ladle which would represent the truck-load.

Desulphurisation is favoured by holding the iron molten in ladles if manganese be present, and probably in any case. On the truck receiving the pig iron is a framework cradle for removing it when cold, a crane being used to handle it, and transfer its load to shipping cars. By means of suitable tracks, water-cooling appliances, trucks, cranes, engines, &c., all the pig iron from a large plant of furnaces may be cast, cooled, and loaded for shipment at one point without a pig being touched by hand.

The following is an estimate of the cost of the use of sand for casting pig iron, and of the saving which would result from the use of this apparatus :—

Cost to Producer.

	Dollars.
Making up sand-pig beds per ton	0·10
Carrying and loading pig per ton	0·15
Sand per ton, 2½ per cent.	0·02
	0·27

Cost to Consumer. Melting in Cupola.

Assumed average freight on sand per ton of iron	0·03
Unloading and charging	0·01
Limestone to flux	0·03
Coke to melt	0·02
Disposing of 100 lbs. of slag	0·03
Loss of iron in sand and transit	0·01
Loss of iron in slag, 15 per cent. in 100 lbs.	0·08
	0·21
Total	0·48

Deduct.

Moulds	0·07
Labour	0·06
Supplies	0·02
Wear and depreciation	0·03
Total	0·18
Net saving to consumer	0·30

DISCUSSION.

Mr. BAUERMAN said that no mention had been made of granulated slag or slag sand, which had been proposed for use instead of sand in pig beds.

Mr. E. P. MARTIN, Vice-President, asked whether the method was really in operation, or whether it was simply brought forward as an idea. Every one agreed that if sand could be got rid of from pig iron used in making steel it would be very desirable. In addition to what had been referred to by Mr. Bauerman, some persons had been using pig iron cast in fine ore with promising results.

With regard to dealing with pigs after they were cast, there were several plans. One had been adopted on a rather large scale at the Dowlais Works at Cardiff. Instead of breaking the pigs and allowing them to bleed, as they frequently did when broken hot in the beds, they were lifted in combs after they had cooled and transferred by cranes to a hydraulic breaker, from which the broken pigs dropped into waggons with very little trouble and cost.

Mr. E. WINDSOR RICHARDS, Past-President, thought that the author of the paper made a great deal too much of the small quantity of sand adhering to pig iron. The author mentioned as much as 3 per cent.; but he did not think there was anything like that quantity, or even anything like 1 per cent.; and in order to get rid of such a small quantity of sand as that, and to adopt this very complicated turn-table arrangement of carrying 20 tons of metal from the blast-furnace to a place some distance off, and with the trouble of teeming that metal into this revolving turn-table, was purchasing the elimination of 1 per cent., if they give the author credit for as much sand as that, a great deal too dear. In fact, it did not seem to him at all a practical or commercial suggestion.

Mr. J. S. JEANS suggested that the Secretary should obtain some particulars of a system which he (Mr. Jeans) had seen in

visiting pig iron works in Germany last year. There they were casting in chills, and they seemed to attach a great deal of importance to that system.

Mr. W. H. BLECKLY, Vice-President, said the author seemed to lay great stress upon the unfortunate user having to pay for the sand. Well, if the user could not protect himself by not paying for the sand, he deserved to have to pay for it. It was the usual thing to make an allowance for the sand.

Mr. WINDSOR RICHARDS said the matter referred to by Mr. Jeans was very old in South Wales. Thirty or forty years ago they were running the iron into cast iron rolls, and they were able to judge of the quality by the fracture; but in running it into chills there was considerable difficulty.

CORRESPONDENCE.

Mr. R. A. HADFIELD, member of Council, had read with interest the excellent paper by Mr. H. D. Hibbard. The matter taken up was one that, quite apart from the use of any particular appliance or mechanical arrangement, should be of special importance to those makers of steel who were striving to produce the highest quality. For example, without doubt, as Mr. Hibbard pointed out in paragraph 4, there would be a great advantage in breaking up a chill-made pig for examination of the fracture, as to an experienced eye the depth of chill would be almost equal in value to a chemical analysis of the iron for silicon. Pigs cast in sand were very deceptive as regarded that point, owing to the much longer time taken to cool down. As regarded the use of the apparatus he described, it seemed to him (Mr. Hadfield) that something on these lines would be well worth a trial. Speaking personally as a consumer, he would willingly give a little higher price for chill-cast pigs.

Mr. HENRY D. HIBBARD, in reply to the discussion, stated that he had not had a chance of casting pig himself by this

method, but Mr. Edmund Tosh, of Ulverston, had cast pig iron on a somewhat similar principle, and must be able to tell the Institute something of the possibilities of the system.

Replying to Mr. Martin, he had no doubt that the pigs could be cooled sufficiently by the use of water to be handled unbroken, or with each bed in but few pieces, if it were found to be more advantageous to break them cold than hot. The labour of making up the pig beds and the presence of sand on the pig would still be avoided.

Replying to Mr. Windsor Richards, he must dissent from his views that sand pig usually carries less than one per cent. of sand. When the matter was first forced upon his attention some nine years ago, the silica in his basic open-hearth slags ran so high that it could only be accounted for by allowing three per cent. to the sand on the pig. This seemed at first to be incredibly large, but a careful estimate, made by calculating the surface of the pig used and measuring in many places the depth of the sand coating, yielded about the same figure. As might be supposed, the furnace practice was bad while using such pig, but he did not then know where to get a more suitable supply of cheap iron. Another point was that pig iron producers would not be likely to grant a concession of a quarter (28 lbs.) in the ton for sand, if their sand bills did not show them that the pig carried at least that much.

On the motion of the PRESIDENT, a vote of thanks was passed to Mr. Hibbard for his communication, and the following paper was then read :—

A NOTE ON THE MISSING CARBON.

By T. W. HOGG (Newburn Steel Works).

In his recent valuable paper on the hardening of steel, Mr. H. M. Howe uses the term "Missing Carbon" to denominate that portion of the carbon existing in water-quenched steel, which is found by taking the difference between the Eggertz coloration test in the normal or annealed steel, and that found in the same steel in its hardened condition. That the difference of colour intensity of solutions of the same steels annealed and hardened is due directly to a peculiar modification of carbon, or of a carbide of iron present in rapidly cooled steel is certain, but the precise nature of this modification has still to be discovered.

Whatever this modification may be, the carbon concerned in it is capable of exact measurement in this way, and although the late J. S. Parker noticed that there was an important difference in the coloration tests obtained in hardened and annealed steel, the writer was the first to use this as a rough measure of the quantity of carbon in the hardening state, and attention was directed to this by Mr. J. W. Spencer in the *Journal of the Iron and Steel Institute* (1880), No. II., p. 443. I am not aware that Osmond and Werth described this fact previously.

When iron is treated with nitric acid a whole series of complex reactions may present themselves, depending upon the relative proportions of the two substances towards each other. When the nitric acid is in excess, and the proper conditions as to temperature and strength of acid observed, we may have formed ferrous nitrate, ferric nitrate, and ammonium nitrate. If the acid is extremely dilute there is no disengagement of gas, as the strength of the acid is increased, hydrogen is given off, and then with a still stronger acid the three gases nitrogen, nitrous oxide, and nitric oxide are given off together in variable

proportion; these being the product of the action of hydrogen, nitrosidic acid (hyponitrous acid), and hydroxylamine upon each other. When the iron is in excess there are formed successively hydrated peroxide of iron, hydrated protoxide of iron, and finally black magnetic oxide itself, with complete conversion of the original nitric acid into free ammonia.

On treating steel with an excess of nitric acid of moderate strength, the freshly liberated or nascent carbon or carbide enters into combination with the gases evolved at the same time. A nitro-carbon compound is thus formed, which passes into solution upon the application of heat with the well-known brown colour. A further continued application of heat causes complete destruction of this colouring matter, with the slow evolution of carbonic acid gas, small quantities of cyanogen compounds, and a colourless viscid decomposition product. The characteristic appearance of the products of the action of moderately dilute nitric acid upon slowly cooled, cast, and rapidly cooled steels, disappears with the use of a large excess of extremely dilute cold acid, which causes the separation of the whole of the carbon in the amorphous form, free from iron, and containing only a very small proportion of occluded nitrogen oxides.

The following nitro-carbon compounds yielded by the same steel—a 1 per cent. carbon steel, in its cast and annealed condition—were obtained by treating the steel in the form of borings with a large excess of nitric acid (1·2 specific gravity), and preventing any considerable rise in the temperature by surrounding the containing vessel with cold water.

The compounds filtered off and dried over concentrated sulphuric acid have the following composition:—

	Annealed.	Cast.
Iron	73·73	2·54
Carbon	8·43	49·41
Water	7·26	22·40
Nitrogen	3·20	8·25
Oxygen (by difference)	7·38	17·40
Total	100·00	100·00

By treating ferro-manganese in the same manner the nitro-carbon compound separated had the following composition :—

Carbon	40·36
Water	35·73
Nitrogen	9·50
Mineral matters	7·80
Oxygen (by difference)	6·61
Total	100·00

In these analyses, the water obtained in the combustion has not been calculated to hydrogen, and this, it would appear, is present to a considerable extent not in combination with oxygen. After spending some time over this point I found that these nitro-compounds are subject to gradual decomposition, even at the ordinary temperature. The kind of action which takes place is shown in the following experiment, wherein a current of pure dry air was passed over the substance for half-an-hour at each temperature. The nitro-compound obtained from ferro-manganese was in this case air-dried only, and the weight lost is compared with the gain in the potash bulbs and calcium chloride tube :—

Heated to	80° C.	100° C.	130° C.	160° C.
Total loss	Per Cent. 3·1	Per Cent. 16·35	Per Cent. 22·75	Per Cent. 38·75
Absorbed in $CaCl_2$ tube	2·1	10·65	14·55	19·7
Absorbed in KHO bulbs	1·2	6·25	8·90	18·7
Total gain	3·3	16·9	23·45	38·4
Increase over loss	0·20	0·55	0·70	...

The experiment at 160° C. was spoiled, owing to the substance suddenly decomposing with slight violence. Another experiment was conducted, using the substance previously dried over sulphuric acid.

Substance heated to 150° C. :—

	Per Cent.
Loss of weight	25·37
Absorbed by $CaCl_2$	12·85
Absorbed by KHO	14·85
	27·70
Increase over loss of weight	2·33

The potash, after these absorptions, contained small quantities of cyanogen, and only a portion of the total gain is due to carbonic acid. Supposing the total increase in weight of the KHO bulbs was due to the oxidising action of the air, the increase over the loss of weight of substance should be 10·80 per cent. Most of the absorption is evidently due to the gradual evolution of nitrogen oxides.

The whole of the nitro-compounds separable from steels in varying conditions are of a very unstable character. The ordinary strength of nitric acid, viz., 1·2 specific gravity, used for coloration tests gives, however, results which are sufficiently distinctive to allow of the following classification :—

Condition of Carbon in Steel.	Action of Cold Acid.
(*a*) Amorphous carbon	Black, insoluble.
(*b*) Normal carbide	Black, magnetic, insoluble.
(*c*) Dissolved carbide	Brown, insoluble nitro-carbon compound.
(*d*) Unknown carbide	Either immediately decomposed as CO_2, or forms a colourless compound.

Although all ordinary cast, hammered, or rolled steels give a small amount of carbon, insoluble in hot dilute hydrochloric acid, I do not think that this is also insoluble or undecomposable by nitric acid; it is only in particular cases, such as "black file steel," or well-annealed high-carbon steel, with low manganese, that the condition (*a*) sometimes makes its appearance. As this is in steels well below the limit of saturation with carbon, it is not easy to understand how it can exist. According to what is known with regard to cementation, it seems most improbable that free amorphous carbon could continue to exist for any length of time without entering into combination with the iron. This amorphous carbon is not attacked by any ordinary treatment with the hot acid. The black magnetic substance separated by the cold acid in the condition (*b*) is decomposed by hot nitric acid, the iron passing into solution, and the brown nitro-carbon compound then formed also dissolves. In the condition (*c*), which I consider characteristic of dissolved carbide (dissolved in the steel), the brown nitro-carbon compound is formed at once by the cold acid. In the condition (*d*), all the evidence we have at present points towards this as being identical with the so-called hardening carbon.

In the following table I give a list of ascending carbon steels which I have selected from a large number of cases. As a rule these steels have all been hardened in cold brine, and to obtain the maximum hardening effect, plates of about a ¼ inch thick were used. The percentage of manganese in these steels varied between 0·4 and 0·6. The colour-tests in the hardened steels, with one or two exceptions, were all obtained by hammering them until they disintegrated into splinters; the splinters were then tested against drillings from the same bars in their hammered normal condition.

Column 1 gives the actual carbon by combustion.

Column 2 shows colour-test of the hardened steel.

Column 3 shows percentage of "missing carbon."

Column 4 shows the percentage of missing carbon with regard to total carbon present.

Column 1.	Column 2.	Column 3.	Column 4.
Per Cent.	Per Cent.	Per Cent.	Per Cent.
0·10	0·06	0·04	40
0·14	0·10	0·04	28·57
0·21	0·10	0·10	47·62
0·25	0·13	0·12	48·00
0·30	0·17	0·13	43·33
0·35	0·17	0·18	51·43
0·39	0·23	0·16	41·02
0·45	0·25	0·20	44·44
0·50	0·28	0·22	44·00
0·62	0·41	0·21	33·87
0·70	0·35	0·35	50·00
0·75	0·32	0·43	57·33
0·84	0·35	0·49	58·33
0·92	0·41	0·51	55·43
1·00	0·50	0·50	50·00
1·25	0·74	0·51	40·80
1·50	1·10	0·40	26·66
1·64	1·33	0·31	18·90
1·70	1·35	0·35	20·58
2·40	2·10	0·30	12·50
3·10	2·82	0·28	9·03
6·50	6·50	0·00	0·00

The alloy, containing 3·1 per cent., contains only traces of amorphous carbon, manganese, and silicon.

The last figures are those obtained from a sample of ferro-manganese. The rapid cooling does not appear to affect the carbon in this alloy.

It is noteworthy that on comparing the percentages of "missing carbon" with regard to the total carbon present, that the steels which seem to be able to retain the largest proportion of their carbon in this peculiar condition are, with one or two exceptions, those which lie between 0·70 and 1·00 per cent.

The various questions of a purely physical nature concerned with the phenomena of hardening are now increasing so rapidly that, for the time being, the chemical side is receiving a somewhat disproportionate share of attention. Probably this may be on account of the generally limited nature of the kind of chemical examination which has to be resorted to. Bearing in mind that the few facts of a purely chemical nature which are known to be intimately related to the physical results are based upon the effects of retarded or accelerated solution, the writer feels confident that, although the labour may at first sight appear to be great in proportion to the results obtained, in time some simple chemical discovery will do much towards rendering the hardening of steel easier to understand.

DISCUSSION.

Professor ROBERTS-AUSTEN, member of Council, said the recognition that carbon appeared to be "missing" when determined by the coloration method was, as was well known, by no means new. Eggertz himself had directed attention to the fact. Some experiments made, many years ago, by Dr. Ball in Professor Austen's laboratory had shown that a direct relation existed between the amount of carbon which appeared to be "missing" and the tenacity of steel; and the results of these experiments would, he hoped, be published as a contribution to the present discussion. Osmond and Werth were also among the earlier experimenters to insist on the fact that the coloration method did not reveal the presence of all the carbon actually in the steel, and they showed that the amount of carbon which was wanting, increased with the percentage of carbon.

Mr. Hogg's paper was more important than it might at first sight appear to be, because it afforded additional evidence that carburised iron, like many metallic alloys, falls into line with ordinary saline solutions. It was well known and widely accepted that in dilute saline solutions the salt present in solution might really be dissociated into its *ions*. All the chloride of sodium, for instance, in a dilute solution was not present as NaCl but as Na + Cl. In the same way, carbide of iron (probably FeC_3) when dissolved in iron might really be in part dissociated, and there was probably a direct relation between the proportion of carbide so dissociated and the amount of carbon which was found to be "missing" in conducting the Eggertz test. Without diagrams it was not easy, Professor Austen said, to make this point clear, but he considered that it is of no small importance to insist on the analogy of carburised iron and "solidified solutions," and the views then expressed he fully shared with his friend Mr. Osmond, and neither of them had ever faltered in the position they had taken up with regard to the carburisation of iron in connection with the theory of the hardening of steel.

CORRESPONDENCE.

Mr. J. S. De Benneville thought that Mr. Hogg's valuable note bore directly on the relation between iron and carbon in steel. The colour test was intimately related to the carbide of iron, generally accepted as a carbide of constant composition, and of formula R_3C nearly, and Mr. Hogg showed that its decomposition gives a complex organic compound, or free carbon, according to the conditions under which it reacts. Hardening carbon followed the same rule, forming "carbon dioxide, or a colourless compound." On slow cooling from the liquid state, carbon, in the presence of iron, preferably combined with it to form Fe_3C, the dissociation point, above which it was unstable, lying near 700 degrees. Beyond the dissociation point either a new carbide was formed or carbon separated as free carbon in the polymeric forms familiarly known, or free carbon was distributed intermolecularly through the mass of the alloy as a solid solution.

Mr. Moissan's experiments on the dissociation and volatilisation of carbon showed that in the presence of other elements the dissociated molecular, or even atomic carbon, eagerly combined with them. But if, in hardened steel, the carbon was dissolved in and not combined with the iron, why is not the missing or hardening carbon—for Mr. Hogg's identification of them seemed well grounded—the chief factor in dilute solutions or low carbon steels? Mr. Hogg said, on the contrary, that the largest percentage of "missing" carbon was found between ·70 and 1·00 per cent. of carbon. Also that the separation of free carbon was dependent on the strength of the acid solution, and its proportion varied in passing from acid of one strength to another; and, moreover, such residual carbon was obtained more readily from cast and annealed steel than from hardened steel—from steels in which Fe_3C was practically the only carbide present. That was, the separation of free carbon was not *primâ facie* evidence that the carbon was present merely dissolved in the iron. On a solution theory, the combination of sulphur and iron was not due to the formation of a readily fusible sulphide of iron.

Where metals dissolved each other—physical mixture in distinction from chemical combination—they would be found to be essentially metallic in nature, but the combination of metal and metalloid was generally of a more intimate character. If carbon was dissolved in the iron of hardened steel, should not—1. The properties of such an alloy be additive, for example, as to specific volume? 2. The dissociation (or even ionisation) of the carbon be greater as the solution of the carbon in iron was more dilute? 3. On dissociating carbon by iron at low red-heat, did the carbon dissolve forming hardening carbon, or was the chemical compound Fe_3C formed? From Mr. Hogg's interesting and suggestive note, nitric acid in its action on iron was to be classed with hydrochloric and sulphuric acids. Iron carbides could be brought under the same group as other carbides, and as yet there did not seem good ground for placing them by themselves.

Mr. R. A. Hadfield, member of Council, had read Mr. Hogg's paper with considerable interest. It had long been a matter of knowledge in the Sheffield steel trade that the colour-test was apt to give misleading results, though the analyst was in no way at fault, but he believed that Mr. J. W. Spencer was the first to explain in a satisfactory manner how that difficulty arose. He thought Mr. Hogg's further paper a very important communication, and another link in the chain against allotropy. If the carbon might vary in the way in which it was proved it did in hardened steel, we surely need not make matters more complex before we solved what were the natures of the changes in the carbon itself. He believed Mr. Stead had further confirmed Mr. Hogg's work quite recently, and had found clear evidence in support of the explanation offered by Professor Arnold in his paper to the Institute a few months ago regarding the particular combination formed by what he called the saturation-point of carbon steel—that was, at about 0·80 per cent. carbon.

Mr. F. Osmond wrote that he did not accurately know who had been the first to point out that the colorimetric method of determining the amount of carbon in hardened steel shows an apparent loss of carbon. Neither Mr. Werth nor he, although then unaware of the experiments of Mr. Hogg, had claimed priority

for the observation, but had cited, more especially, Professor Eggertz himself, and Mr. Woodcock, as having published the fact before them, and they had only attempted to ascertain what had become of the missing carbon.* It was to this investigation that Mr. Howe referred.

The experiments of Mr. Hogg went far to prove that the carbide Fe_3C should be subdivided into segregated and dissolved carbon. The distinction was a very probable one, and the more so because it was perfectly in accordance with the indications afforded by a study of the micro-structure of steel. It was equally probable that a portion of the dissolved carbide was dissociated with its *ions*, and these free carbon *ions* corresponded with the missing or hardening carbon. In support of that suggestion, it was shown by Mr. Hogg that the missing carbon passed through a maximum when the total carbon rose progressively. The facts collectively were, therefore, in accordance with the ordinary laws of solution. For this reason, while admitting that lengthy researches were still necessary to settle all the details of this complex question, Mr. Osmond assented to the conclusions of the author. He had himself arrived at similar conclusions in his study of chrome steel.†

Mr. E. H. SANITER said that the noteworthy fact pointed out by Mr. Hogg, that steel containing about 0·89 per cent. of carbon showed the highest percentage of "missing carbon," led him to endeavour, by calculation based on Mr. Hogg's results and Professor Arnold's saturation-point theory, to ascertain if the table of missing carbon determinations was confirmatory or otherwise of Arnold's theory.

The data of the calculation were as followed:—

Deducted from Mr. Hogg's table that 0·89 per cent. of carbon in chilled steel, *i.e.*, Arnold's 100 per cent. $Fe_{24}C$, gave a colour equal to 0·385 per cent. of carbon as normal carbide, *i.e.*, Fe_3C.

That in chilled steel up to 0·89 per cent. carbon, all the carbon would exist as $Fe_{24}C$.

That in chilled steels over 0·89 per cent. carbon, the steel would consist of varying amounts of $Fe_{24}C$ and Fe_3C, according to the excess of carbon over the saturation-point, which (the

* *Annales des Mines*, 8th Series, vol. viii. pp. 26–32.

† *Journal of the Iron and Steel Institute*, 1892, No. II. p. 127

saturation-point) is lowered as the carbon increases over 0·89. For instance, a chilled steel containing 1·7 per cent. carbon would have its saturation-point lowered to 0·76 carbon; that was to say, that only 0·76 per cent. of the carbon could exist as $Fe_{24}C$, the rest of the iron being required to form Fe_3C.

In chilled steel up to 0·89 per cent. carbon, the calculation was:—

$$\frac{\text{Total per cent. of C in steel} \times 0{\cdot}385}{0{\cdot}89}$$

should give a small result equal to colour test of hardened steel.

In chilled steels over 0·89, it was assumed that the carbon existing as Fe_3C would give its full colour value, while that existing as $Fe_{24}C$ would be in the ratio of 0·89 : 0·385. From this method of calculation the following table had been constructed from Mr. Hogg's figures:—

Calculated Composition of Chilled Steel. Fe.	Calculated Composition of Chilled Steel. Fe_3C.	Calculated Composition of Chilled Steel. $Fe_{24}C$.	Total Carbon. Hogg.	Colour Test on Chilled Steel. Hogg.	Calculated Result to compare with Colour Test.	Difference between Test and Calculation.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
88·7	...	11·3	0·10	0·06	0·03	−0·017
84·2	...	15·8	0·14	0·10	0·06	−0·04
76·3	...	23·7	0·21	0·10	0·09	−0·01
71·8	...	28·2	0·25	0·13	0·11	−0·02
66·1	...	33·9	0·30	0·17	0·13	−0·04
60·5	...	39·5	0·35	0·17	0·15	−0·02
55·9	...	44·1	0·39	0·23	0·17	−0·06
49·2	...	50·8	0·45	0·25	0·19	−0·06
43·5	...	56·5	0·50	0·28	0·22	−0·06
29·9	...	70·1	0·62	0·41	0·27	−0·14
20·9	...	79·1	0·70	0·35	0·30	−0·05
15·3	...	84·7	0·75	0·32	0·32	0
5·1	...	94·9	0·84	0·35	0·36	+0·01
...	0·5	99·5	0·92	0·41	0·41	0
...	2·0	98·0	1·00	0·50	0·50	0
...	6·35	93·35	1·25	0·74	0·78	+0·04
...	10·7	89·3	1·50	1·10	0·98	−0·12
...	13·05	86·95	1·64	1·33	1·20	−0·13
...	14·1	85·9	1·70	1·35	1·27	−0·08
...	26·25	73·75	2·40	2·10	2·13	+0·03
...	38·4	61·6	3·10	2·82	2·79	−0·03

Of the steel containing under 0·89 per cent. carbon, 6 out of 13 of the calculated results did not differ more from the actual tests than might occur in duplicate colour tests, while of those over 0·89 per cent. carbon, 5 out of 8 did not differ more than duplicate tests might do, while in several cases the agreement was remarkable.

He should be glad if Mr. Hogg could throw any further light on his results, which might be affected by the impurities contained in his specimens, of which a full analysis was desirable.

The agreement between the calculated and actual test was sufficiently remarkable to be worthy of the attention of the supporters of the allotropic and chemical theories of the hardening of steel by chilling.

If, however, it were argued that the whole of the carbon was affected in the same manner by chilling carbon-iron alloys, containing over 0·89 per cent. of carbon, Mr. Hogg's figures would not support the argument; as, for instance, taking the sample containing 3·1 per cent. carbon, and calculating in the same manner as for steel containing under 0·89 per cent. carbon, the following figures would be obtained :—

Total Carbon (Hogg).	Colour Test on Chilled Steel (Hogg).	Calculated Result by Arnold's Theory.	Calculated Result assuming all the Carbon to be Altered by Chilling.
Per Cent.	Per Cent.	Per Cent.	Per Cent.
3·1	2·82	2·79	1·34

These figures were in his opinion a strong argument in favour of the hardness of chilled steel being due to the formation of a definite carbide of iron, which could only be present in a proportion limited by the excess of carbon over a saturation-point somewhere about or under 0·89 per cent.

Mr. Saniter had noticed in etch polishing chilled specimens of cement bar containing 1·0 per cent. of carbon, that the cementite (Fe_3C) veins were softer than the ground mass ($Fe_{24}C$?), which seemed to indicate that Fe_3C is not hardened by chilling.

In applying these foregoing facts to the allotropic theory, we had :—

(1.) The statement of the allotropists that carbonless iron cannot be maintained in the hard state by chilling.

(2.) That when carbon is present, it acted as a break to maintain the hard modification.

(3.) In addition to these, it might further be fairly argued that when the carbon exceeded the saturation-point, that excess no longer acted as a break to maintain the iron with which it was combined in the hard modification.

It would therefore appear that the break action attributed to carbon by the allotropists only came into force within certain limits, which were also within the limits prescribed by Arnold for the formation of his suggested $Fe_{24}C$.

In conclusion, he felt inclined to disagree with Mr. Hogg that hardening carbide "decomposes to form CO_2, or forms a colourless compound." He thought that the colour tests in the table on page 183, made on intensely chilled specimens, showed that hardening carbide gave a coloured compound, although not so intense as normal carbide.

Mr. Albert Sauveur, Chicago, Illinois, has forwarded the following contribution to the discussion:—

If we look over Mr. Hogg's table giving the percentages of "missing carbon" in a series of ascending carbon steels, we notice that, as the carbon increases to about 1 per cent., those percentages vary relatively little. With two exceptions, between 40 and 58 per cent. of that element is found missing in every instance. As the carbon content of the steel rises above 1 per cent., however, the percentages of missing carbon decrease rapidly. With 3 per cent. of carbon in the steel, only 9 per cent. of that amount is missed; with 6·50 per cent. of carbon, none of it escapes the colour test.

It does not seem possible to explain this apparent anomaly with our present knowledge of the modifications of carbon in steel, and no doubt others must have tried in vain to account for it.

As will be shown presently, in examining the microscopical structure of hardened steel, our failure in this direction is due to the fact that we generally supposed that the quantity of hardening carbon retained in the quenched metal by sudden cooling is proportional to the amount of total carbon. As a matter of fact, this is true only when the steel contains less than about 0·90 per cent. carbon. With further increase of carbon, the proportion of hardening carbon to the total carbon decreases rapidly.

To make this matter clear, let us briefly recall what are the constituents of hardened steel, as well as their mode of occurrence and distribution in steels of various carbons.

All carbon steels, quenched above the critical range (and such is the case for Mr. Hogg's samples), considered as aggregations of mineralogical components, are made up of one or two of the three constituents—ferrite, cementite, martensite.

Ferrite is a mineralogical name for carbonless iron.

Cementite is a mineralogical name for the normal carbide, Fe_3C.

Martensite is found at a high temperature only, and is transformed during slow cooling (at the lower critical point) into a softer constituent (pearlyte). It can, however, be retained in the cold metal by sudden cooling, and it is to this retention of the martensite that quenched steel owes its hardness. Of the true chemical composition of martensite, however, we have no direct evidence. According to the allotropists, it is composed of iron in an allotropic state holding carbon in diffusion. The carbonists tell us that it is iron *plus* hardening carbon, and Professor Arnold claims that it is a definite chemical compound of carbon and iron, $Fe_{24}C$.

In a recent communication* to the American Institute of Mining Engineers, it has been conclusively shown that the carbon in martensite varies all the way from about 0·12 per cent. to about 0·90 per cent., according to the carbon content of the steel and the quenching temperature. It cannot be, therefore, a definite compound of carbon and iron. It seems highly probable that martensite is made up of a matrix of iron (allotropic or not), throughout which the carbon is diffused, either as such or as a definite carbide.

In the paper just referred to, I have ventured to say that it was possibly, if not probably, the normal carbide, Fe_3C itself, which was thus diffused in the martensite, and that the volatilisation of some of its carbon, when the steel is dissolved in cold dilute hydrochloric or sulphuric acid, was due to its extremely minute state of division.

The true chemical nature of martensite has, however, little bearing upon the point at issue. It is only necessary for our purpose to remember, first, that the carbon of hardened steel may occur in two different forms, *i.e.*, as *cementite carbon* (the carbon

* "The Microstructure of Steel and the Current Theories of Hardening," by Albert Sauveur, American Institute of Mining Engineers, September Meeting, 1896.

of the carbide Fe_3C), and as *martensite carbon*, generally called hardening carbon (at least including the hardening carbon); and second, that all the "*missing carbon*" *is derived from the martensite carbon;* for the cementite of hardened steel is in every particular similar to the normal carbide of the slowly cooled metal, and therefore none of its carbon will escape the colorimetric test.

Bearing this in mind, let us examine the distribution as to quantity of the three constituents of hardened steel, with a view of ascertaining what relation they bear to the amount of total carbon in the steel.

This is shown graphically in Fig. 1. The microstructure of four samples of hardened steel containing respectively 0·09, from 0·12

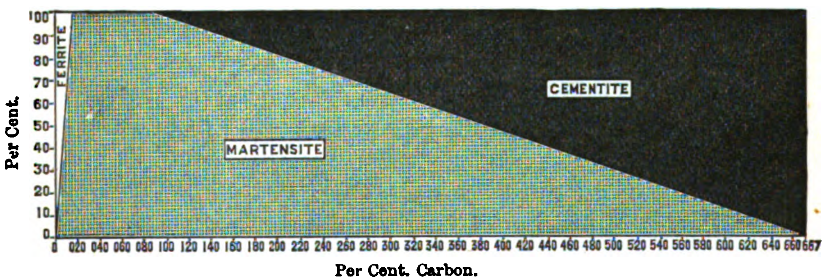


FIG. 1.—Microstructural Composition of Hardened Carbon Steel.

to 0·90, 2·50 and 6·67 per cent. carbon has also been drawn in Figs. 2, 3, 4, and 5, under a magnification of 250 diameters. The martensite is represented by dotted areas, no attempt having been made to indicate its structure, because it was only desired to bring out the relations between the areas occupied by the various constituents. The ferrite has been left white, which is also its colour under perpendicular illumination. In the drawings the cementite is shown in black, in order to distinguish it from ferrite, but under the microscope it appears intensely brilliant with a metallic lustre.

The statement of Fig. 1 is based upon theoretical calculations, and its general accuracy was verified by actual planimeter measurements of the areas occupied by the various constituents, as set forth in detail in the paper already referred to.

From an examination of this diagram it will be seen that when carbon steel is suddenly cooled from a high temperature, if it contains very little carbon, the quenched metal is made up of martensite and ferrite (see Fig. 2), the amount of the latter constituent diminishing rapidly, and soon disappearing as the steel becomes more carburetted. When the metal contains from 0·12 to 0·90 per cent. of carbon, martensite is the only constituent (see Fig. 3). The hardness of this martensite increases of course with its degree of carburisation. When more than 0·90 per cent. of carbon is present in the steel, it contains some cementite (see Fig. 4), which increases in quantity proportionally

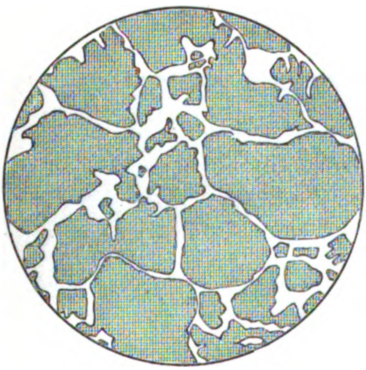


FIG. 2.—Carbon, 0·09 per cent.; Ferrite, 23 per cent.; Martensite, 77 per cent.

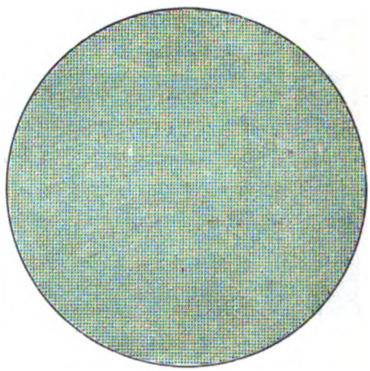


FIG. 3.—Carbon, from 0·12 to 0·90 per cent.; Martensite, 100 per cent.

to the carbon. With 6·67 per cent. of carbon in the steel, the whole mass is made up of the carbide Fe_3C. (See Fig. 5.)

At about 0·90 per cent. of carbon we have a critical point in the microstructure of the steel. Professor Arnold calls it the saturation point; but in order not to confound it with the chemical saturation point of iron for carbon, which occurs at 6·67 per cent. of carbon, the former might be called, somewhat incorrectly, the "structural" saturation point, meaning by it that above that degree of carburisation the steel cannot "structurally assimilate" more carbon. If a larger percentage of that element is present, then the excess of carbon exists structurally free, so to speak, in the shape of the normal carbide Fe_3C, disseminated in small masses throughout the matrix of martensite (see Fig. 4),

of course reducing thereby proportionally the amount of martensite.

It is important to bear in mind that above the structural saturation point a portion of the combined carbon passes readily into the graphitic condition (Ledebur's temper carbon) during annealing, the more readily as we approach the chemical saturation point. This is one of the reasons which renders the preparation of the saturated compound of carbon and iron (Fe_3C) in considerable quantity a matter of great difficulty.

It is not necessary here to review the influence which the impurities generally present in iron and steel, have upon the

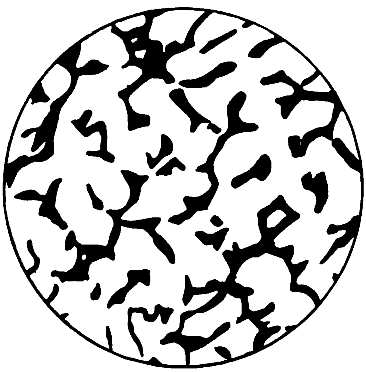


FIG. 4.—Carbon, 2·50 per cent.; Martensite, 80 per cent.; Cementite, 20 per cent.

FIG. 5.—Carbon, 6·67 per cent.; Cementite, 100 per cent.

tendency of the combined carbon to pass into the graphitic state, and upon the position of the chemical saturation point. Their action is now well understood, and has been described clearly in Mr. Howe's "Metallurgy of Steel," and more recently by Professor Ledebur.* It is probable that all impurities lower the structural saturation point, although in very different degree. Indeed, I find that in slowly cooled commercial steel, containing from 0·75 to 1·25 per cent. of total impurities (carbon not included), the structural saturation point is very near 0·80 per cent. of carbon.

Returning to our diagram, it is seen that when hardened

* "On the Modifications of Carbon in Iron." *Journal of the Iron and Steel Institute*, 1893, No. II.

steel contains less than 0·90 per cent. carbon, the whole of it is present as martensite carbon, while in more highly carburetted metal the carbon exists partly as martensite carbon and partly as cementite carbon, the former diminishing, the latter increasing in quantity as the total carbon increases. In this we find the explanation for the rapid fall above 1 per cent. of carbon in the percentages of missing carbons of Mr. Hogg's table. It is because above that point the amount of martensite in the steel, *i.e.*, the amount of material capable of yielding missing carbon, rapidly diminishes, eventually disappearing altogether (at 6·67 per cent. carbon).

In the following table I have calculated the microstructural composition of Mr. Hogg's steels on the basis that the martensite of over-saturated steel contains 0·90 per cent. of carbon. This can conveniently be done as follows:—

Let c be the percentage of total carbon in the steel, x the percentage of martensite, and y the percentage of cementite. We have

$$1.\quad x + y = 100.$$

And since martensite contains 0·90 per cent. of carbon, and cementite (Fe_3C) 6·67 per cent., we have

$$2.\quad \frac{0{\cdot}90x}{100} + \frac{6{\cdot}67y}{100} = c.$$

These two equations give

$$y, \text{ or percentage of cementite} = \frac{100c - 90}{5{\cdot}77}$$

and therefore

$$\text{percentage of cementite carbon} = \frac{(100c - 90)\, 6{\cdot}67}{577}$$

the balance of the carbon being martensite carbon.

Columns 3 and 4 of the same table show the amounts of carbon present as martensite carbon and cementite carbon, while in the last column the percentages of missing carbon have been calculated as missing martensite carbon (leaving out the decimals) instead of missing total carbon.

†Total Carbon in Mr. Hogg's Steels.	Microstructural Composition.		Martensite Carbon.	Cementite Carbon.	Missing Carbon.	Missing Total Carbon.	Missing Martensite Carbon.
	Martensite.	Cementite.					
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
0·10	85 M + 15 F	0	0·10	0	0·04	40	40
0·14	100	0	0·14	0	0·04	29	29
6·21	100	0	0·21	0	0·10	48	48
0·25	100	0	0·25	0	0·12	48	48
0·30	100	0	0·30	0	0·13	43	43
0·35	100	0	0·35	0	0·18	51	51
0·39	100	0	0·39	0	0·16	41	41
0·45	100	0	0·45	0	0·20	44	44
0·50	100	0	0·50	0	0·22	44	44
0·62	100	0	0·62	0	0·21	34	34
0·70	100	0	0·70	0	0·35	50	50
0·75	100	0	0·75	0	0·43	57	57
0·84	100	0	0·84	0	0·49	58	58
0·92	99·65	0·35	0·90	0·02	0·51	55	57
1·00	98	2	0·89	0·11	0·50	50	56
1·25	94	6	0·85	0·40	6·51	41	60
1·50	90	10	0·81	0·69	0·40	27	49
1·64	87	13	0·78	0·86	0·31	19	40
1·70	86	14	0·77	0·93	0·35	21	45
2·40	74	26	0·67	1·73	6·30	12	45
3·10	62	38	0·56	2·54	0·28	9	50
6·50	3	97	0·03	6·47	0·00	...	...
		Mean percentage of missing martensite carbon,				.	47

With 6·50 per cent. carbon there is no missing carbon, but then the metal contains only 0·03 per cent. of martensite carbon, a quantity too insignificant to be detected.

It is seen that above 1 per cent. of carbon there is no indications of a fall in the proportion of missing martensite carbon. From one end of the series to the other we find, with two exceptions, from 40 to 60 per cent. of missing carbon, or an average of 47 per cent., which is raised to 49 per cent. if we leave out the two abnormal cases yielding only 29 and 34 per cent. respectively.

He concludes, therefore, that, roughly, half of the martensite carbon escapes detection by the colorimetric method, bearing in mind that this means half of the total carbon, if the steel contains less than 0·90 per cent. of carbon, but that the proportion of the martensite carbon (and therefore of the missing carbon) to the total carbon rapidly decreases with further increase of carbon.

This is confirmed by Mr. Howe's carbon determination * of

* "Hardening of Steel," H. M. Howe, *Journal of the Iron and Steel Institute*, 1895, No. II. p. 258.

seven samples of the same steel containing 0·21 per cent. carbon, and quenched at different temperatures above the critical range. He finds an average of 45 per cent. of missing carbon.

Messrs. Osmond and Werth,* who, if I am not mistaken, were the first to call attention to the "presence" of missing carbon when hardened steel is treated by the Eggertz method, also find 47 and 51 per cent. of missing carbon in steel containing 0·90 per cent. of carbon.

Our statement that about half of the martensite carbon escapes the colour test when steel is hardened in the usual manner, is therefore well confirmed. Too much importance should not be attached to the fact that the maximum amount of missing carbon in Mr. Hogg's table is found when the steel contains from 0·75 to 0·90 per cent. of carbon, because, if we consider the somewhat erratic results which the method is liable to give, the number of instances is altogether too small to carry much weight. If it were found that the mean percentage of a great many determinations is sensibly higher in this region, then only should we be justified in inferring that steel structurally saturated, or nearly so, yields a larger proportion of missing carbon.

To sum up: When hardened steel is dissolved in nitric acid in the usual way, one half of the martensite carbon behaves exactly like the normal carbide Fe_3C, in imparting colour to the solution, while the other half fails to colour it, in this way escaping detection. Shall we infer from this that the carbon is present in the martensite in two different modifications? As already stated, previous investigations have led me to ask whether it were not the normal carbide Fe_3C which was diffused through the iron matrix of the martensite; and here, indeed, we have strong indications that at least one half of the martensite carbon exists as diffused Fe_3C. But what of the other half? Is it not also the carbide Fe_3C, but in such a minute state of division that it is readily volatilised? Of course the question might easily be dismissed by saying that it is "hardening carbon," but until we know what hardening carbon is—if, however, its

* *Annales des Mines*, 1885. The authors also heated some steel in nitrogen previous to quenching, and found a little over 50 per cent. of missing carbon. Heating the steel in hydrogen increased the yield of missing carbon to 65 and 77 per cent., while heating it in vacuum and quenching in mercury reduced it to 35 per cent.

existence is not a myth—this explanation will not be very satisfactory. Is hardening carbon simply dissolved carbon? If so, I fear, indeed, that we cannot explain the hardening of steel without calling in Mr. Osmond's theory based upon the existence of a hard allotropic state of the iron itself. For how can we conceive that, say, 0·50 per cent. of carbon—*i.e.*, one part of carbon, be it of adamantine hardness, disseminated throughout 199 parts of soft iron—can confer to the quenched metal its extreme hardness?

Mr. J. E. Stead, member of Council, believed it was generally admitted that Mr. J. W. Spencer was the first to make known publicly that the colour given to a nitric acid solution of hardened and softened steel was widely different, that there was less colour from hardened than from the same steel annealed. Mr. Hogg's paper gave a quantitative determination of the loss of carbon colour due to hardening.

It was most interesting to note that the greatest loss of colour producing carbon was at or about the saturation-point of Professor Arnold for commercial steels, or about 0·8 per cent. carbon. If it were assumed that in the hardened steel all the carbon above 0·80 per cent. remained as Fe_3C, and that Fe_3C gave its full colour to nitric acid, and that the 0·80 per cent. of the carbon in the hardened steels yielded 0·33 per cent. of its colour, we should obtain the following figures, compared with Mr. Hogg's actual results:—

Per Cent.	Carbon Colour Found by Mr. Hogg. Per Cent.	Calculated. Per Cent.
0·80	...	0·33
0·84	0·35	...
0·92	0·41	0·33+(0·92 − ·80)=0·45
1·00	0·50	0·33+(1·0 − ·8) =0·53
1·25	0·74	0·33+(1·25 − ·8) =0·78
1·50	1·10	0·33+(1·50 − ·8) =1·03
1·64	1·33	0·33+(1·64 − ·8) =1·17
1·70	1·35	0·33+(1·7 − ·8) =1·23
2·40	2·10	0·33+(2·4 − ·8) =1·93
3·10	2·82	0·33+(3·1 − ·8) =2·63

There seemed to be a divergence between the calculated colours and those found, but as a whole, considering the char-

acter of the colour test, they approximately confirmed the assumption stated.

Some allowance should be made for the diminishing proportion of perlite in the steels as the carbon increases above 1·0 per cent. If this correction is made, the calculated results come closer to what is actually found in the high carbon steels than the above table shows. Thus, after making the correction, the calculated carbon colour of the 3·1 per cent. steel is 2·83 per cent. against 2·82 per cent., the amount found by Mr. Hogg.

Mr. HOGG said, in reply, that he must express his general agreement with many of the views given in the discussion. It might be as well to point out, however, that Eggertz only referred to the effect of "hardening" upon the colour test subsequently to the account of the experiments described in the *Journal of the Iron and Steel Institute*, to which he had already referred.

There seemed to be everything in favour not only of considering all the alloys as solidified solutions, but also that those bodies existing isolated and suspended in the solidified mass as definite compounds would be present in the complex molten fluid in a more or less dissociated condition. The application to the ferro-carbon alloys of the laws of solution and dissociation were so explicitly treated by Benneville in the *Journal of the Iron and Steel Institute* (1895, No. I.), that there was no necessity to repeat them, and it would be difficult to profitably add to his views.

With regard to the dissociation of dissolved carbide of iron referred to by Professor Roberts-Austen, the doubtful point seemed to be whether the normal carbide dissociated into free iron and some other kind of free carbon than amorphous carbon, or into some other unstable carbide. The dissociation of carbide of iron by prolonged exposure to a temperature below fusion, with the formation of free amorphous carbon, was one of the few facts which seemed to be certain. It was very important to differentiate between this kind of dissociation and that to which Professor Roberts-Austen referred.

The separation of amorphous carbon from steel by means of a solvent might be, as was well known, carried out in such a manner that certain evidence might be obtained that it was in the steel in such a condition, and he (Mr. Hogg) had been careful

to refer to the effect of extremely dilute nitric acid as an example of the separation of amorphous carbon entirely as a reaction product. It might be considered as fairly certain that there was never any appreciable quantity of "hardening" carbon formed under the conditions mentioned in Mr. Benneville's third query.

Although, as Mr. Hadfield pointed out, it was now well known that the colour test was apt to give misleading results, he thought also that it was frequently credited with inaccuracy unduly. There were several sources of error apart from the effect of hardening upon it, but actual variations in the real carbon existed much more frequently than careful steel manufacturers might wish to believe. He might remind Mr. Hadfield that Osmond himself stated that the allotropic theory must differentiate itself effectively in connection with special facts, and that it must be acknowledged that carbon presented, in its relations with iron, a certain number of peculiarities inseparable from its presence.

Both Mr. Stead and Mr. Saniter pointed out the apparent agreement between the proportions of "missing carbon" and the results calculated from Arnold's sub-carbide as a basis. Certainly the relationship appeared to be very close, but too much reliance should not be placed upon arrangements of figures of this kind, especially as Mr. A. Sauveur had arranged another table, showing that the "martensite" carbon was intimately related with the "missing carbon;" and Mr. Sauveur, if he (Mr. Hogg) was not mistaken, doubted the existence of this sub-carbide, or at any rate did not believe that it had anything to do with the hardness of steel. It was very probable, as Mr. Saniter suggested, that variable proportions of impurities might appreciably influence the "missing carbon;" but as the series of steels given were, with the exceptions mentioned, all pure carbon steels, complete analyses would be of little importance.

He might state definitely concerning Mr. Sauveur's very able speculations, that the very nature of "martensite" precluded any special objection that might be taken to his theory that it was in this that the missing carbon had its origin. However definite martensite might be as a microscopic revelation, its composition chemically was so elastic that it might well include much of a purely chemical nature that might be discovered hereafter concerning the variations of carbon in steel and its relatives. There

was no reason why the supposition should be questioned that the Fe_3C might be in such a minute state of division that it admitted of ready complete oxidation. Such ready oxidation would, however, take place if the carbide was in solution and dissociated, as pointed out by Professor Roberts-Austen. Arnold's attenuated subcarbide $Fe_{24}C$ would also be readily oxidised, also his $Fe_{10}C$.

With regard to Mr. Sauveur's concluding sentence, "For how can we conceive that, say 0·50 per cent. of carbon—*i.e.* one part of carbon, be it of adamantine hardness, disseminated throughout 199 parts of soft iron—can confer to the quenched metal its extreme hardness?" Mr. Hogg said that, even supposing this was not true, would it not be just as reasonable to wonder why a substance possessed of such versatile capabilities as carbon did not work some remarkable transformation in a metal it possessed some affinity for? Admitting the truth of it, it was no more astonishing than that a perfectly mobile liquid like water should be transformed into a jelly by one per cent. of gelatine, or that the union of a white metal with a white alloy should produce a beautiful ruby-coloured one, or that by a mere rearrangement of its parts a perfectly harmless nitrite should produce one of the deadliest of poisons.

There was nothing difficult in the conception that the hardness of water-quenched steel was caused by a peculiar condition of the carbon, or that it was caused by Osmond's hard allotropic condition of iron, or by Mr. Howe's carbide of the hard allotropic iron. The difficulty was in forming a reliable estimate of the different kinds of evidence submitted. Until the doubtful evidence was eliminated and the good made more complete, they could not hope for confidence in any of them.

On the motion of the PRESIDENT, a vote of thanks was passed to Mr. Hogg for his communication, and the following paper was then read:—

A NEW WATER-COOLED HOT-BLAST VALVE.

BY WILLIAM COLQUHOUN, ASSOC. M.INST.C.E., LIVERPOOL.

IN these days of high temperatures, the serious effects of prolonged stoppages in blast-furnace practice has directed the attention of engineers and managers to the importance of providing themselves with appliances that will not only stand the high temperature for the longest possible period, but which are easily accessible for repairs, and of such a character that the most exposed parts of the apparatus can be changed without any long interruption of the blast.

Having these requirements in view, a great many attempts have been made to provide a hot-blast valve, the more exposed parts of which are artificially cooled. In some instances the cooling agent employed has been a current of cold air, by means of a connection with the cold-blast main; but the cooling effect was found to be insignificant. The application of water was, therefore, the only effective method of keeping the valve-seat and valve-slide cool. Its use, however, presented serious difficulties and even danger, as no water-cooled valve could be considered safe that exposed the circulating pipes (having possibly sliding gland connections) to the high temperature of the blast; for if any fracture takes place, the hot-blast main may be flooded before the accident is apparent, and in many situations the water will find its way into the tuyeres. The valve patented by Mr. Jenkin Lewis provides against any serious accident of this character, and since its introduction during the last three or four years into a large number of the more important plants throughout the country, there has been no reason to complain of its safety or efficiency. It consists of a brick-lined wrought-iron or cast-steel casing and hood, within which is riveted a flange for holding the valve-seat, to which it is bolted with three or four bolts. A coil of 1-inch water-pipe is cast within the valve-seat, which is a ring cast in good grey iron, and faced true with

the flanges of the valve casing. Where the water-supply may be relied upon to be clean, plentiful, and under fair pressure, it is sufficient for the pipes to make one complete turn round the valve-seat, and to couple with the supply and exhaust by means of gun-metal unions. But in cases where the water is dirty, it is advisable to cast the pipes in two half-bends, and couple them together with a short U-bend, through which, when detached, a pricker may be passed to clear obstructions. This alternative method is plainly shown in Plate LIV., the V-pipe connection being dotted. The interstices between the seat and the casings are filled up with purimachos cement, and the back of the seat is protected by well-fitted fireclay blocks. In practice, it has been found that a water-cooled valve-seat rarely requires changing if it has been properly tested in the first instance, and its shape prevents it from warping and consequent leakage of blast.

The seat may be changed, however, by slinging the valve down, taking out the brickwork, and knocking out the four or more studs or bolts holding the seat to the inner ring. The slide is a cast-iron equal-sided disc, faced on both sides so as to be reversible. The disc has an extension or arm upon which a hollow cast-steel trunnion is bolted, forming a centre on which the disc may be moved radially, so that when full shut it is concentric with the valve-seat, and when full open is withdrawn within the hood so as to leave a clear passage. It is actuated by a wrought-iron lever keyed to the steel trunnion, and carrying a balance slightly less heavy than the disc. The water circulating-coil is cast in the metal of the disc, and the ends of the pipe protrude right and left at the centre upon which the radial motion acts, at right angles to the valve faces. The two halves of the hollow steel trunnion are passed over these pipe-ends, which are then threaded, and a pair of gun-metal asbestos-packed swivel glands screwed on to stop any leakage of blast. The supply water therefore enters through the swivel gland into one end of the trunnion, passes round the valve, and exhausts at the other end. The steel trunnion fits loosely on the arm of the valve-slide, and a wedge-shaped projection on the rim of the disc, engaging with the tapered side of a stop-block at the moment when the slide is full closed, brings it against the face of the seat. The blast, however, does this even more effectively, and

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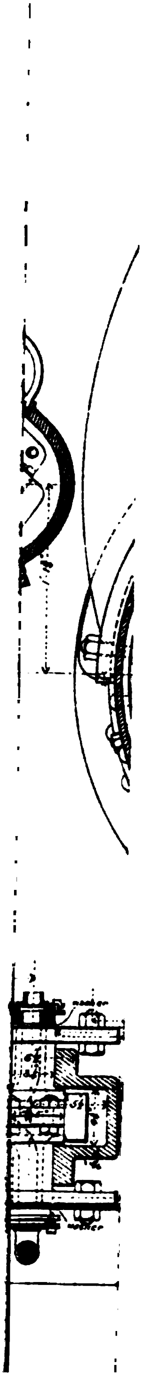


completely seals the valve, unless warping has taken place; in that event it can be easily felt by the workman that the contact is imperfect. The trunnions turn in bearings bored, half in the valve hood and half in a lid fitted thereto, the lid giving access into the interior, and covering an opening sufficiently large to admit of the passage of the slide. The slide may either be turned face about, or changed completely in less than fifteen minutes. The advantages claimed for the valve are apparently well substantiated in practice, now that certain defects in the earlier design have been removed; and it is particularly valuable for throttling a very hot and cutting blast in half- or quarter-closed positions. The moving parts are extremely simple; there are no rods or glands to pack and keep tight; the water-pipes at every point in the interior of the valve are enclosed in the metal of the various parts; and, finally, the slide may be rapidly changed without taking down or dismantling the valve.

It is owned by Messrs. Francis Morton & Co. of Liverpool, and made in all sizes from 15 inches to 30 inches diameter, and in small sizes for tuyere valves.

DISCUSSION.

Mr. E. WINDSOR RICHARDS, Past-President, did not know whether Mr. Colquhoun claimed any monopoly for this thing being dipped into the barrel in this manner vertically, so as to be out of the range of the heat. He would only say that it was not novel, because in 1868 or 1870 he himself designed a valve at the Ebbw Vale Works, which was very effective. He did not like to criticise this in any way, because he had just looked at the paper, but he would be glad to criticise it through the *Journal.*

Mr. JEANS thought it would interest the meeting to have Mr. Richards' opinion as to the valve in operation at Glengarnock.

Mr. WINDSOR RICHARDS said that was Mr. Jenkins Lewis's valve, and it was a very effective one.

CORRESPONDENCE.

Mr. W. PERROTT noted that the valve described by Mr. Colquhoun was used at the works of the Lilleshall Company, Limited, where it was found satisfactory. It was much more durable than other valves used for the same purpose.

On the motion of the President, the thanks of the Institute were given to the author for his paper, and the following paper was read:—

THE ESTIMATION OF SULPHUR IN IRON ORES.

By R. W. ATKINSON, B.Sc., F.I.C., and
A. J. ATKINSON, F.I.C.

In the matter of the limits of permissible sulphur in iron ores it is our experience that buyers are becoming more and more exacting in their requirements, and as this necessitates greater care and accuracy in making the analysis when the quantity of sulphur involved is so minute, we have thought that a description of the method which, in our hands, gives, with very little trouble, results not often differing by more than two or three units in the third decimal place in duplicate analyses, may be of interest to many members of the Institute.

For many years we have abandoned the aqua-regia method of sulphur estimation, and have used a modification of Eschka's method of determining sulphur in coal, which was first suggested by Mr. Nakamura, a student in the Imperial College of Engineering, Tokio, Japan. We roast the ore with sodium carbonate, dissolve in water, wash by decantation, acidify the filtrate with hydrogen chloride, heat to boiling, and precipitate with hot barium chloride solution. After standing over night, we filter, dry, ignite, and weigh.

The most important features of this method are:—

(1.) The whole of the sulphur present as pyrites or calcium sulphate is obtained in a solution free from iron.

(2.) The degree of acidity of the solution may be as much or as little as is desired.

(3.) The absence of nitrates in the precipitation by barium chloride.

The details of working are as follow:—For each analysis we take two portions of the dried ore (previously passed through a sieve of ninety meshes to the inch) weighing 5 and 6 grammes.

We also weigh out 5 and 6 grammes of pure sodium carbonate, then grind together in a steel mortar the ore and sodium carbonate until the mixture is apparently quite uniform. It is then brushed on to a platinum tray of an oblong shape, about 5 inches long and 2 inches broad, with a vertical rim all round ½ inch high. The mixture on the tray has a thickness of about ⅛ inch. We then place the trays on clay-pipe stems within a cold gas muffle. The muffle is of the largest size, so that it heats up slowly. The gas is then lighted, and the temperature slowly rises in about half-an-hour to a dull red-heat barely visible in daylight. The gas tap may now be opened a little wider, and the temperature brought up to bright red-heat in another hour. After remaining at this temperature for fifteen or twenty minutes the reaction is usually complete. We judge when the roasting is complete by the changes in colour of the mixture. At the beginning the colour is pale-brown, varying, of course, according to the nature of the ore. The first stage consists in the dehydration of the ore, which then becomes purplish-red, and by continued heating a further change takes place, the red colour changing to an olive-green. When the whole mixture has assumed this tint without any of the red colour remaining, we find that the reaction is at an end. Sometimes, if the temperature is allowed to rise too high, the green colour becomes more pronounced, owing to the formation of sodium manganate, and the mixture may become fused in parts. We try to avoid this, as it makes the solution of the substance more difficult, but it has no other effect. The mixture ought to be only slightly sintered if the temperature has been properly regulated.

When the trays have been removed from the muffle and have cooled down, we wash the mixture into a No. 4 beaker by means of a gentle stream of hot water from a wash-bottle, shake it round, and then allow it to settle. When clear the solution is decanted from the residue through a Swedish paper into a No. 5 beaker, and the residue in the No. 4 beaker is washed with hot water. In order to prevent the finely divided oxide of iron passing through the paper we add 1 gramme of the same sodium carbonate as was used at first. This causes the residue to settle rapidly, and we never find any tendency for the oxide of iron to run through the paper.

The filtrates are next acidified with 10 cc. and 12 cc. respectively of pure hydrogen chloride, and placed on the hot plate to expel the carbonic acid, and to heat them to boiling. They are then quite colourless and transparent, and when boiling, 10 cc. and 12 cc. of a hot solution of barium chloride (containing 100 grammes $BaCl_2 2H_2O$ per litre) are added, shaken, and set aside for about eighteen or twenty hours.

When the percentage of sulphur in the ore is under 0·02, the barium sulphate is not at once precipitated, and, in any case, the whole of the barium sulphate is only thrown down after standing many hours. The precipitate is next filtered through No. 590 Schleicher and Schülls papers, 9 centimetres diameter, the ash of which is under one-tenth milligramme, and, washed with the usual precautions, first with hot acid water, and finally with pure hot water, dried, ignited, and weighed.

The sodium carbonate we use is the purest granulated obtainable, and each bottle, after thorough mixture, is tested, the weight of barium sulphate obtained from 20 grammes noted, and an allowance made for the weight used in each experiment with ore. The amount yielded by 5 grammes of the specimen we are now using is 0·0004 grammes.

We have compared the results by the roasting process with those obtained by the aqua-regia method, and have found them to agree when the latter method is carefully carried out, as the figures given below will show. In carrying out the aqua-regia method we have found it necessary to evaporate to hard-dryness, redissolve in hydrogen chloride, and evaporate several times with fresh acid in order to thoroughly expel all nitric acid. It is also necessary to add a considerable excess of barium chloride solution, and to allow the whole to stand at least twenty-four hours. With these precautions, and making allowance for the barium sulphate derived from the nitric acid, the agreement between the two methods is quite satisfactory, although we generally find, in Bilbao ores, that the percentage by the aqua-regia method is 0·002 to 0·004 lower than by the roasting process, a circumstance which we attribute to the solubility of barium sulphate in an acid solution of ferric chloride.

Some comparative results are given below. Nos. 1 to 4 are

various kinds of Bilbao iron ore, and 5 and 6 are puddling-cinders:—

Nos.	Aqua-Regia Method.			Roasting Method.		
	Experiment 1.	Experiment 2.	Average.	Experiment 1.	Experiment 2.	Average.
1	0·017	0·020	0·019	0·023	0·021	0·022
2	0·030	...	...	0·031	0·031	0·031
3	0·036	0·032	0·034	0·038	0·036	0·037
4	0·061	0·063	0·062	0·065	0·067	0·066
5	0·261	0·260	0·260	0·259	0·243	0·251
6	0·301	0·297	0·299	0·300	0·299	0·299

CORRESPONDENCE.

Mr. Bertram Blount wished to indicate certain points in the paper which appeared to him open to criticism. It might be at once admitted that the elimination of iron from the solution in which the determination of the sulphur was ultimately effected by precipitation with barium chloride was an appreciable advantage, although the authors' own results (coinciding with general experience) showed that accuracy could be attained by the *aqua regia* method, provided that this was properly carried out. But in securing this advantage certain drawbacks were encountered. Thus, in the first place, it was by no means an easy matter to obtain sodium carbonate free from sulphates; the authors were fortunate in being able to procure as good a sample as that concerning which they gave particulars. The preparation of pure sodium carbonate in the laboratory was comparatively tedious, and needed a good deal of precaution. If this reagent, being essential to the process, was not very approximately pure, the objectionable necessity of making a correction from a blank experiment, involving the deduction of a value of the same order of magnitude as that given by the ore itself, at once arose.

In this connection it was proper to observe that a similar criticism applied equally to the application of a correction for the amount of sulphate yielded by the nitric acid used in the *aqua regia* process. In this case, however, there was no real difficulty in preparing pure nitric acid by redistillation in the laboratory, and the use of a correction should not be tolerated. A more serious objection to the authors' process was that sodium carbonate when heated by means of coal-gas—even when protected from unrestricted contact with the products of combustion by the use of a muffle—was apt to absorb oxides of sulphur, which would be reckoned as derived from the ore. The only way to avoid this contingency was to use a spirit or benzoline burner as a source of heat. With this modification, the method might well prove preferable to that commonly adopted.

Mr. T. Vaughan Hughes considered that the authors were to

be congratulated upon their work in connection with the estimation of sulphur in iron ores. Having adopted some of their previously described processes, and found them excellent in yielding accurate results, he felt sure that if this present analytical method were followed, true results would also be obtained. Fresenius had long since pointed out that even with zinc blende, treatment with acids alone does not decompose them. His own experience amply confirmed this, and especially so with some blendes from Wales and the Isle of Man. Comminute these blendes to possible limits, the ordinary text-book directions for decomposing the weighed sample would fail in practice. Fusion with the usual "mixture," or with sodium carbonate containing a small amount of sodium peroxide, were, he thought, the only reliable methods.

The fritting process of Messrs. Atkinson would, he believed, save much time in the subsequent dissolution of the sulphur compounds formed. The only doubtful point was this: what might be the limit of contained pyrites in the sample of iron ore which would cause the mere fritting to be ineffective? Perhaps the authors had investigated this matter. Again, the average works' laboratory was not, in all probability, so well equipped as that of Messrs. Atkinson. The "Works Chemist" conscientiously enough supplied the analytical data to the purchaser of the ore or his representative. Often a works' "Lab" was provided with a muffle heated by coal or coke; sometimes a superior quality of coal-gas was supplied; occasionally an ill-scoured and non-purified product of coal distillation was used.

Cracked and badly fitting muffles were, he thought, general. The diffusion of the furnace gases into the interior of these muffles was a matter of course. Under such circumstances a sulphur determination in a shallow, partly covered, platinum dish might lead to "high" results, and to the inevitable business squabble between buyer and seller.

Could not Messrs. Atkinson supplement their excellent paper by devising a simple sulphur-absorbing cover capable of use under the circumstances just described?

Mr. D. A. SUTHERLAND had read the paper of Messrs. Atkinson with some interest, as for the past five or six years another

modification of Eschka's process had been in use in his laboratory for a similar purpose. He had also used the process for the estimation of elements other than sulphur. But dealing with the question of sulphur as referred to in the paper, he would like to remark that he had been in the habit of using anhydrous potassium carbonate, and sometimes a mixture of potassium and sodium carbonate. He had also found it advantageous to use some magnesia in order to prevent any fusion such as was referred to in the paper. In fact, he had obtained very good results by the use of the Eschka process exactly as originally described. The use of potassium carbonate alone was not advisable, for obvious reasons, and at least an equal weight of pure magnesium oxide should be used with it. In his laboratory the process had been carried out in the muffle much as described, except that he had found very shallow porcelain dishes quite satisfactory in use. A solution of the residue in hot water was filtered, but before adding hydrochloric acid a few drops of bromine water were added, in order to ensure that any sulphites or hyposulphites present should be completely oxidised. He had every reason to be satisfied with the results obtained, not only with reference to sulphur in coal or iron ore, but in most cases where the sulphur had to be estimated in substances other than metals.

Mr. Alexander E. Tucker had used the same process as that described by Messrs. Atkinson, but had invariably evaporated the water extract to dryness after acidifying with hydrochloric acid, in order to separate any silica which might have become soluble. The old method of fusion with sodium carbonate and a small quantity of nitre differed only in degree from that of Messrs. Atkinson. The formation of soluble silicates would occur in both. Mr. Tucker had not experimented on the quantity of silica rendered soluble, this depending on the heat used, but it appeared to him certain that some would always be formed when the ores were roasted with sodium carbonate. Possibly on this account by non-evaporation to dryness, the larger percentages of sulphur obtained by the authors may be accounted for. It would probably be impossible to filter off the silica from the solutions when a low heat had been used in roasting without evaporating to dryness, but the production

of sulphate of barium in the beaker containing it would gather it, and bring it down mechanically. Messrs. Atkinson did not appear to filter at all after the addition of acid, but if the acidified solution was allowed to stand for some hours, a slight sediment would frequently form which has every appearance of silica.

Further, when fusion or roasting with soda was adopted, great caution must be exercised to avoid absorption of sulphur from gas. This absorption might be very serious. When fusion was adopted a spirit flame should always be used. Both methods were preferable to the *aqua regia* method, as in that method, when pyrites was present, free sulphur was of course separated, and at the boiling temperature of the acid might be partly volatilised. Further, the time and material used in consequence of the repeated evaporations necessary were serious drawbacks, so that the advocacy of Messrs. Atkinson's method, with the exception of the detail mentioned, was to be welcomed.

A vote of thanks was passed to the authors for their contribution.

The PRESIDENT said that the proceedings were now practically brought to a close, with one important exception. The position of the President of the Institute involved some devotion of time, some sacrifice of other engagements, and some sense of responsibility, and, so far as he was himself concerned, a still greater sense of deficiency. But at any rate, the position had large compensations. He did not refer to the important status conferred upon any one whom the members were kind enough to place in the presidential chair, nor to all the kind attentions of which the President was the recipient, because he shared them with the other members generally. But he referred particularly to the privilege accorded to the President of being the spokesman of the members in recognising the attentions that they received in the various localities to which they paid their autumn visit. He accordingly rose for the purpose of proposing a very cordial vote of thanks, and although it might be adopted by a comparatively small number of persons, he thought he was justified in saying that he held the proxies of

several hundred members. They were not indeed proxies in legal form on stamped paper, not proxies lodged with the Secretary forty-eight hours before the meeting, but they were proxies that had been verbally communicated to him during the last few days by the members, who were all full of recognition of the admirable arrangements made for their reception, their entertainment, and instruction by the programme which had been so carefully worked out, and to which so much labour had been devoted by the gentlemen who had formed the Reception Committee. He begged to move—

"That the best thanks of the Iron and Steel Institute be hereby tendered to his Excellency the President of the Deputation of Biscay, to the Alcalde of Bilbao, and to the President of the Local Committee for their kind reception of the Institute.

"That the best thanks of the members be hereby given to the Vice-Presidents, the Hon. Secretaries, and the members of the Local Reception Committee for the great cordiality of the welcome extended to them, and for the arrangements ably planned and successfully carried out for the convenience, instruction, and pleasure of the members during the present meeting.

"That the best thanks of the members be also hereby given to the Director of the Provincial Institute and the President of the Chamber of Commerce, for their kindness in granting the use of their building for the purposes of this meeting; to the proprietors and managers of the various works and mines of the district, for their great courtesy in receiving the members, and for the permission given to inspect their establishments; to the harbour authorities, and to the various railway and tramway companies for the facilities given; and to the committees of the various clubs for the privileges accorded to the members of the Institute."

Mr. E. P. MARTIN, Vice-President, seconded the motion, which was unanimously adopted.

Professor W. C. ROBERTS-AUSTEN, C.B., Member of Council, in proposing the vote of thanks to the President, said that if he were to express all that the members of the Institute would desire with regard to this vote of thanks, or even if

he were to say all that he felt, it would be necessary to detain them for some time; but this would not be in accordance with Sir David Dale's wishes, and he would therefore do little more than say how grateful they all were to the President for the admirable way in which he had discharged his duties, and how glad they all were that the metallurgical interests of two great countries, England and Spain, should have been fittingly united by Sir David's occupancy of the chair. They were also fully sensible of the services Lady Dale had so gracefully rendered the Institute by her presence among them, and Professor Austen felt sure that it would be understood that Lady Dale's name was included in the vote of thanks. It was pleasant to remember that several prominent members of the Institute—including the President, Mr. Martin, and Mr. Windsor Richards—had a direct interest in the metallurgical industries, and were, in a sense, "at home" in Bilbao. They had, however, with true Spanish politeness, striven to place their works and their houses at the disposal of the members of the Institute, and had succeeded in making the members feel that their possessions were, as Spaniards say, shared with their guests.

Dr. W. Anderson, C.B., seconded the motion, which was unanimously adopted.

The President thanked the members for the kind manner in which they had been good enough to recognise the very small services of a merely official character which he had been able to render. Probably it would be more fitting when he surrendered the presidential chair to his friend Mr. Martin to allude to that which he felt in accepting the presidency of the Institute—namely, that he did so with a full sense of his inability to take part in the technical discussions, as his predecessors had done, or to guide the meeting in its deliberations on technical papers. But he knew that he should be surrounded, as he was on that occasion, by those who were able, and who had been kindly willing, to supplement his deficiencies in that respect, an obligation that he most fully recognised in connection with the present meeting.

VISITS AND EXCURSIONS AT THE SPANISH MEETING.

The Autumn Meeting of the Iron and Steel Institute, which was held at Bilbao on Sepember 1 and 2, 1896, was organised under conditions differing considerably from any of its predecessors; for although it has, in former years, been held farther afield, as, for instance, in Styria and in Hungary at the Vienna Meeting, and over a great part of the United States and Canada after the New York Meeting, this was the first occasion on which a ship was specially chartered to convey the members, and to serve as a floating hotel during the meeting. This step was necessary, as, in spite of the great increase in size of the Biscayan capital, the hotel accommodation was found to be insufficient to bear the addition of several hundred visitors at the time when Bilbao and the adjacent seaside resorts were crowded with summer visitors. The Orient Steam Navigation Company, to whom the service of detailing a suitable ship was entrusted, selected one of the finest vessels of its fleet, the R.M.S. *Ormuz*, for the commission.

The *Ormuz* was designed and built by the Fairfield Shipbuilding and Engineering Company, Limited, Glasgow, specially for the Australian passenger service of the Orient Steam Navigation Company, Limited. Her principal dimensions are as follows:—Length over all, 481 feet; length between perpendiculars, 465 feet; breadth moulded, 52 feet; depth, 37 feet; displacement at load-line, 10,500 tons at 26 feet; gross register tonnage, 6116; effective horse-power, 8500; class in Lloyd's register, 100 A1. Triple expansion engines, cylinders, 46, 73, and

112 inches. Stroke, 6 feet. Boilers—of steel, cylindrical, seven in number. Working pressure, 150 lbs.

The *Ormuz* has five decks, viz., the promenade deck, about 9 feet above the upper deck, and capable, therefore, of being used by passengers in all weathers; the upper deck, which is of steel, covered with teak 3 inches thick; the main deck, also of steel, covered with pitch pine 3 inches thick; the lower deck, also of steel from the line of the engine and boiler-room casing out to the ship's side, and covered with 3 inches of pitch-pine; and the orlop deck, which is of yellow pine 2½ inches thick. The beams to all these decks are of great strength, being of the Butterley section, and presenting a neat appearance to the eye compared with the bulb plate and angle irons commonly used.

The party on board numbered 250, the Council being represented by Sir Lowthian Bell, Sir James Kitson, Mr. E. Windsor Richards, Mr. W. H. Bleckly, Mr. G. J. Snelus, Mr. A. Thielen, Professor W. C. Roberts-Austen, and Mr. J. E. Stead.

A number of members, including the President, Sir David Dale, and Mr. Edward P. Martin, proceeded to Bilbao overland or in private yachts.

The party mustered at St. Pancras Station, Midland Railway, at 10.55 A.M. on Saturday, August 29, and were despatched in two special trains to Tilbury, where they were embarked immediately on arrival. Sir Bernhard Samuelson accompanied the party from Tilbury, and was landed with the pilot in Dover Bay about 7 P.M. The ship then proceeded on her course down Channel, passing the Casquets early on Sunday morning, and Ushant about 4 P.M. Very fine weather was experienced at starting, but on Sunday morning it became dull and grey, with a strong westerly wind and a sufficient sea to be rather trying to the less experienced passengers, in spite of the large size of the vessel. Notwithstanding the unfavourable weather, there was a good attendance at church in the morning, the service being taken by Dr. W. Anderson, C.B., and Professor Roberts-Austen, C.B. Among the many attractions of the *Ormuz* deserving notice was the string band, under the leadership of Mr. G. S. A. Foreman, Professor at the Guildhall School of Music. The orchestra discoursed excellent selections of music, and was much appreciated by the passengers. During Sunday night the weather became more propitious, so that on Monday morning the Cantabrian Mountains came in sight early, and at 11.30 A.M. the *Ormuz* anchored at her appointed station in Bilbao Bay.

Bilbao, the busiest port in Spain, is beautifully situated on both banks of the river Nervion. Its population (December 31, 1894) is 61,107. Its buildings are almost entirely modern, the old ones having perished from bombardment and conflagration. The most frequented promenade is El Arenal. The Campo de Volantin is also a fine promenade, well laid out. The principal churches are the Basilica of Santiago (a typical example of early Spanish Gothic, fourteenth century), San Antonio Abad, in the Plaza del Mercado (one of the oldest, but much restored), Los Santos Juanes, in the Calle de la Cruz, San Nicolas de Bari, facing the Arenal promenade. Lastly, there is the Santuario de Nuestra Señora de Begoña, a spacious Late Pointed church, with a modern arched gallery and a shady terrace, at the top of a long flight of 320 steps. The chief public buildings are the Diputacion Provincial, Plaza Nueva; the Town Hall; the new Theatre in the Plaza de Arriaga; the Custom House; the Plaza Nueva; the Plaza Circular, with a fine bronze statue of Don Diego López de Haro, who founded Bilbao in 1300; Fronton Euskalduna, in the Calle de Hurtado de Amézaga, a recently erected covered tennis-court capable of accommodating 3000 persons; and the bull-ring, with seats for 11,000 spectators. The banks are the Bank of Bilbao (Plazuela de San Nicolas), the Bank of Spain (Succursal), in the Calle del Banco de España; and the Bank of Commerce (Calle de la Estacion). The bridges are those of San Anton, San Francisco, La Merced, and the Arenal. There is also the swing bridge of San Augustin, built in 1892.

A large and influential Reception Committee was formed, with Excmo. Señor Don José, Mª de Arteche Presidente de la Excma. Diputación de Vizcaya, and Señor Don Emiliano de Olano, Alcalde-Presidente del Excmo. Ayuntamiento de la I. Villa de Bilbao, as Presidents; Excmo. Señor Don José de Vilallonga and Señor Don Adolfo de Urquijo e Ibarra as Vice-Presidents; and Mr. William Gill and Señor Don Julio de Lazúrtegui as Honorary Secretaries. The Committee was composed of the following noblemen and gentlemen:—Excmo. Sr. Don Martín Zabala, Senador Vitalicio del Reino; Excmo. Sr. Don Victor de Chávarri, Senador del Reino; Excmo. Sr. Don Francisco Martinez Rodas, Senador del Reino; Sr. Marqués de Casa Torre, Diputado á Cortes; Don José Maria Martinez de las Rivas, Diputado á Cortes; Don Benigno Chávarri, Diputado á Cortes; Don Eduardo Aznar y Tutor, Diputado á Cortes; Don Juan T. de Gandarias, Diputado á Cortes; Don José Maria Paredes, Comandante de Marina del Puerto de Bilbao; Don Manuel de Goyarrola, Vice-Presidente de la Excma.

Diputación Provincial de Vizcaya; Don Luis M. de Aznar y Tutor, Diputado Provincial; Don Fernando de Olascoaga, Diputado Provincial; Don Plácido Allende, Diputado Provincial; Don José Camiruaga, Concejal del Excmo. Ayuntamiento de Bilbao; Don Flavio Echevarria, Concejal del Excmo. Ayuntamiento de Bilbao; Don José M. Basterra, Concejal del Excmo. Ayuntamiento de Bilbao; Don Alfredo Acebal, Concejal de Excmo. Ayuntamiento de Bilbao; Don Cosme Palacios, Presidente de la Cámara de Comercio; Excmo. Sr. Don Eduardo Coste, Presidente de la Junta de Obras del Puerto; Excmo. Sr. Don Evaristo Churruca, Ingeniero de la Junta de Obras del Puerto; Don Ramón Adán de Yarza, Ingeniero Jefe de Minas de la Provincia de Vizcaya; Don José Lequerica, Ingeniero Jefe de Caminos, Canales y Puertos; Don Fernando Mieg, Director del Instituto Vizcaino; Don Pedro P. de Gandarias, Senor Don Ramón de la Sota, Don Cosme Echevarrieta, Don Tomás Allende; Don Antonio López, Alcalde de Portugalete; Don Lorenzo de Zaballa, Alcalde de San Salvador del Valle; Don Ignacio de Mericaschevarria, Alcalde de Arteaga; Don Casimiro de Olazábal, Alcalde de Guernica; Don Calixto López, Alcalde de Abanto y Ciérbana; Don Antonio de Balparda, Alcalde de Santurce; Don Hugo Zagastagoitia, Alcalde de Baracaldo; Don Manuel Beltrán de Heredia, Alcalde de Sestao; Don Santiago Diliz, Alcalde de Guecho; Don Manuel Barandica, Director del Banco de Bilbao; Don Marcelino del Rio, Don Manuel Taramona (hijo); Don Recaredo Uhagón, Don Valentin Gorbeña, Don Pablo de Alzola, Don José Orueta, Don Juan Goitia, Don Alberto Palacio, Mr. John Bailey Davies, Mr. Joseph MacLennan, Mr. John MacGillivray, Mr. Frederick MacLeod, Mr. A. Davidson Lammino, Mr. John Browne, Mr. William C. Shoolbred, Mr. Henry A. Sandon, Mr. George E. Woof, Don Alfonso Etchats, Don Pablo Benoist, Mr. Luis Taravellier, Dr. Eugen Erhardt; Don Manuel Losada, Don Juan Carlos Gortázar, Don Manuel Ayarragaray, Don Federico de Echevarria, Don Severino Achúcarro, Don Laureano Gómez Santa Maria, Don Ramon de Ibarra, Don Manuel Lezama-Leguizamón, Mr. E. W. P. Clapham, Mr. C. Lançon, Don Enrique Areilza, Don Juan Basterra, Don Alberto Aznar y Tutor, Mr. Paul Haehner, Don Eduardo Aburto, Don Pablo Carranza, Don Emilio Vallejo, Don Restituto Goyoaga. The Executive Committee consisted of Mr. William Gill, President, Don Tomás de Zubiria, Don Luis M. de Aznar, Don Ramón de la Sota, and Don Julio de Lazúrtegui.

At 2 P.M. the Reception Committee and the Harbour Trustees, on

board their yacht *Elcano*, came out to the *Ormuz*, and the Provincial Deputation welcomed the members to Biscay. After a brief ceremonial address by Don Jose Maria de Arteche, the President, which was suitably acknowledged by Sir David Dale, the members embarked on several small steamers for a survey of the Port and River Works. Full information regarding these important engineering works was given by the President of the Harbour Trust, Don Eduardo Coste y Vildosola, and the chief engineer, Don Evaristo Churruca. The small steamers entered the river Nervion under Don Alberto Palacios' iron bridge, which spans the river at a sufficient height above the water to allow the largest steamers frequenting the port to pass under it. Proceeding along the river, leaving to the right the Bilbao River and Cantabrian Railway Company's Wharfs, the Iberian Tin-plate Works, the Viscaya Iron and Steel Works, the shipyards of the Astilleros del Nervion, the Mudela Ironworks, the Altos Hornos Iron and Steel Works, and the Deputation Railway Wharfs, the steamers arrived at the Axpe Docks, where the members inspected the quarries which furnished the stone employed in the Harbour Works, and also the Electric Installation of Messrs. Coiseau, Couvreux, and Félix Allard, for making the mammoth concrete blocks used in the construction of the breakwater. On landing at Portugalete, afternoon tea was served at the Bathing Pavilion, after which the party returned to the *Ormuz*. The whole of the town of Portugalete and the Suspension Bridge were beautifully decorated with flags in honour of the occasion, and the shipping in the river was also gay with bunting. In the evening the members were invited by the Local Reception Committee to a concert in the Arriaga Theatre, which was specially engaged for the occasion. An excellent programme of Spanish music and dances was rendered, and the crowded theatre presented a most brilliant spectacle, not the least pleasing feature of which was the display of choice bouquets, which were presented by the Committee to every lady. The concert opened and closed with "God Save the Queen," admirably rendered respectively by the Artillery band from Segovia and by the Bilbao Choral Society.

On Tuesday, September 1, after the adjournment of the general meeting, the members were divided into two parties, one of which proceeded by railway to Desierto, where the Altos Hornos Iron and Steel Works were visited, whilst the other party proceeded by electric tramway to the Euskalduna covered tennis-court, where they witnessed an exciting match of the national game of Pelota played by distinguished profes-

sionals, and an exhibition of national dances, concluding with a parade of the traditional giants and dwarfs. In the evening a conversazione was given by the Alcalde of Bilbao in the new Municipal Buildings. The members, with the ladies accompanying them, were received by the Deputy Alcalde and by the Civil Governor of the province. The gathering was a brilliant one, and the architectural features of the imposing buildings were greatly admired.

On Wednesday, September 2, alternative excursions were again arranged, one party proceeding, at the conclusion of the General Meeting, to Sestao, where the Vizcaya Iron and Steel Works and the Iberia Tin-plate Works were visited. The other party proceeded to Guernica, the point of greatest historical interest in the Basque country, where a visit was paid to the Old Parliament House and to the Oak of Guernica, at the foot of which all Spanish sovereigns knelt and swore to protect the liberties of the Basques. Under this oak, the President of the Provincial Deputation said a few eloquent words of welcome, and Don Luis Aznar, speaking in English, gave a short history of the Oak of Guernica. The welcome was gracefully acknowledged by Lady Dale and Sir James Kitson. The Choral Society of Bilbao accompanied the excursion, and sang a selection of Basque songs, including the National Hymn ("Guernicaco Arbola"). The party was subsequently entertained at luncheon by the Local Committee.

The excursion to the iron ore mines, on Thursday, September 3, which must be regarded as the principal event of the meeting, was planned so as to obtain, in a single morning, a general idea of the nature of the deposits, the methods of working them, and of disposing of the production.

Considering the rough and broken character of the ground and the difficulties of access, this was no easy task, although, thanks to the excellent arrangements of the Local Committee, it was carried out with complete success. The party, numbering about 450, assembled on the wharf of the Orconera Iron Ore Company at Luchana at 8.15 A.M., whence the first of the three groups into which the party was divided proceeded by special train, provided by the Orconera Company, to the Orconera district proper, whilst the second and third groups, in another special train, followed the same route to the Orconera Station, and then diverged to the westward by the Gallarta branch railway, their destination being the Somorrostro and Triano disricts.

On arrival at Orconera Station, the train conveying the first group slowed down to enable the visitors to inspect the Company's calcining

kilns, the Espinal and Orconera inclines, and station arrangements for handling the ore. Opposite the telegraph station the visitors alighted, and proceeded on foot to the cradle tips and low roads of the Orconera incline. Up this they were taken in three detachments of 72 persons, the journey up occupying about four minutes. On arriving at the top of the incline, each detachment, after inspecting the drum machinery and automatic knock-off gear, was taken, in the same incline train, to visit the various quarries and points of interest in the following mines:—Orconera, Prevision, and Carmen, the Orconera Iron Ore Company; Union and Amistosa, Don Jose Mª Martinez de las Rivas and Somorrostro Iron Ore Company; Parcocha, the Parcocha Iron Ore Company, Limited; Mendivil and Linda, Messrs. T. de Allende and Norberto Seebold.

After these visits the detachments returned to the Orconera Station and proceeded by train to Mine Concha No. 1, Orconera Company, and the Angle Station "C" of the endless chain of the Société Franco-Belge was inspected. In the meantime, the second group, which had left Luchana for Orconera Station, alighted at the Cadegal foot-bridge and proceeded on foot, escorted by Mr. A. Etchats, Director, and the engineers and staff of the Société Franco-Belge, to visit the mines and works of that Company, including the Cadegal inclines Nos. 1 and 2; the calcining kiln for spathic ore in Mine Concha No. 3, and the endless chain railway, visiting *en route* the Mines Elena (Messrs. J. de Durañona and P. P. de Gandarias), Julia and Adela (Messrs. V. de Chavarri and P. Dario de Arana), Demasia San Benito (Messrs. Ybarra & Zubiria, Gandarias, Taramona, and Société Franco-Belge); and so, following the course of the endless chain railway and Mine Concha No. 1 (Orconera Company) to the Concha Station, where the Angle Station "C" of the chain railway was inspected. Mr. Etchats not only personally conducted the party, but had also gone to the trouble of having roads and paths prepared through all his Company's mines for the convenience of the visitors. The third group, which started with the second, continued in the train to Concha Station, and inspected the operation of the endless chain railway of the Franco-Belge Company at their Angle Station "C." They also inspected the loading arrangements of the Orconera Company for Mine Concha No. 1. The train then proceeded to Gallarta, slowing down opposite the aërial ropeways (Bleichert-Otto system) of the Exma. Diputacion Provincial from Demasias San Antonio and Ser to Ortuella. From this point were seen the Mines and Demasias:—Cristina,

Messrs. Ybarra & Zubiria, Ustara, Allende, and others; Nicanora, Dª Jesusa de Bellido, Ustara, Durañona, and others; Ser, Messrs. Ybarra & Zubiria, Chavarri, Gandarias, and others; Begoña and San Miguel, Messrs. Ybarra & Zubiria, Chavarri, Martinez, Taramona, and others; César, Orconera Iron Ore Company, Limited; Trinidad, Don J. Mª Martinez de las Rivas, Orconera Iron Ore Company, Limited, Arana, Taramona, Chavarri, and Gandarias, and the party returned in the train to the Gallarta Station, where they alighted. After obtaining an interesting view over the valley of Somorrostro, and the battle-fields of the Carlist war of 1873, the party proceeded on foot to Mine Concha No. 1, Demasias San Benito and Bargao. At 12.45 the three parties re-united on the Zarzal embankments near Concha Station, where a large and tastefully decorated luncheon pavilion had been specially erected by the Orconera Iron Ore Company in a position overlooking the inclines of mines Julia and Adela (Messrs. Chavarri & Arana), and railway of La Salve (Don F. Alonso and others); while down in the valley a fine view of the termini of the Provincial Deputation and Franco-Belge Railways at Ortuella and Cadegal respectively was obtained, and magnificent views up the Bilbao Valley and down to Somorrostro and Castro-Urdiales.

The mid-day firing of the shot-holes bored in the mines then commenced, first with the smaller charges, and subsequently with larger chambered mines, under whose influence the square-edged terraced faces seemed to yield easily and to flow into the quarry below, with little other disturbance than thick clouds of brown ore dust, forming a strong contrast to the blue sky overhead. The luncheon, by invitation of the Local Reception Committee, that succeeded, was sumptuous, and in every way a most successful one. It was attended by the principal Provincial and Municipal authorities, the members of the Local Committee, the mines officials, &c. During the progress of the banquet a rock-boring contest was held in front of the pavilion. A series of large stone blocks had been laid down, one for each competitor, the object being to "jump" the deepest hole in a given time. The contest was very active, each man being accompanied by a staff of attendants to clear the dust away by continuously flushing the hole with water and oil.

After several highly eloquent speeches had been made, and the President had returned thanks to the Local Committee for their lavish hospitality, the party returned by the same route to the river, and reached the *Ormuz* about 4.30 P.M., bringing away recollections

of an exceedingly instructive and enjoyable visit. The instructive character of the excursion was greatly enhanced by the fact that members had previously had an opportunity of studying Mr. Gill's exhaustive paper, which gave full details regarding all the mines visited.

At 5 P.M. the President and Council entertained the Local Reception Committee and the leading members of the English colony on board the *Ormuz*, over 500 of whom honoured the Institute with their presence. Refreshments were served on deck, and the orchestra performed a well-selected programme of music, which was greatly appreciated.

During the stay at Portugalete, Mr. Gaminde, the manager of the Orient Company's agents at that port, displayed unflagging energy in making the tug, postal, and telegraphic services as complete as possible.

On Friday, September 4th, the *Ormuz* left Portugalete at 9 A.M. and arrived at Santander about mid-day.

The city of Santander, the most important trading centre in the north of Spain, forming the port of departure for the Transatlantic steamer line, extends for about one and a half miles along the north shore of a broad but rather shallow bay, through which a deep-water channel has been dredged, and the water front is faced by lines of stone quays, allowing large ships to come alongside in places. Some disappointment was therefore felt, and found expression in the local journals, when it was found that the *Ormuz* was not coming into the harbour; but this step, however desirable it might have been, could not be taken, because the only available moorings were occupied by the guardship, the heavy cruiser *Alfonso XII.*, and a large troopship, about to sail with reinforcements for Cuba, so that it was necessary to remain in the roadstead, outside the lighthouse point, and use the tender *Bilbao* for landing and embarking.

On arrival at the quay, the members were welcomed in an eloquent speech by the Alcalde, Don Gonzales Trevilla. The words of welcome were ably translated by Mr. Joseph MacLennan, and were acknowledged by the President. The party then proceeded in two special trains to the charming watering-place of Sardinero in the Bay, where a sumptuous banquet was prepared in the Casino. This building was profusely decorated, and during the banquet an orchestra of guitars played national airs, which were listened to with the greatest enjoyment. Before rising from the tables the President made a brief speech, which was translated into Spanish by Don Isidoro del Campo, thanking the

Alcalde, the Local Reception Committee, the mine-owners, and the people of Santander for the warmth of their welcome. The party then returned by train to Santander, where the festivities were continued in the evening by illuminations, open-air concerts, and theatrical performances, the townspeople being as enthusiastic in their greeting as their neighbours at Bilbao. Saturday, September 5, was given up to visiting the mineral deposits near the town, an attractive programme of excursions having been arranged by the Santander Reception Committee. The party was divided into five groups—the three largest going to the iron ore workings; the fourth, a smaller one, to the zinc ore workings of Reocin; and the last, which was exclusively a pleasure party, to the inland watering-place of Fuente del Frances—the whole being so planned as to enable the members to return to the ship by 6 P.M.

The iron ore workings are situated in two principal localities, namely, Camargo Hill, about 6½ miles south-west, and the Carbarga Mountain, about the same distance south of the town. In the latter, which is the more largely developed of the two, the ores are found in the flank of a line of limestone hill, about four miles in length east and west, as concretionary masses and nodules interspersed in clays, the largest development being at the western end of the ridge in the ground occupied by the Obregon and Cabarceno mines. In the first of these groups, owned jointly by the Viscaya-Santander Mining Company and Mr. J. MacLennan, the ore-bearing clays extend through the low ground, and to a considerable height on either slope of the hill, the deposits being of irregular shape, and varying from a few feet to several yards in thickness, while in some of the hollows between the spurs of the hill as much as 185 feet has been proved by boring. The floor is formed by a bed of dolomite, very irregularly worn into hollows and projecting points, below which the compact lower cretaceous limestone is found. The workings at present are confined to the north side of the hill, the ore-bearing clay being dug along straight faces from 19 feet to 36 feet vertically apart, and connected together by zigzag lines of railway on a gradient of 1 in 30.

The stuff, loaded into waggons carrying 2·6 tons each, of which 33 form a train, is drawn by a locomotive on a falling incline of 1 in 50 for 2¾ miles to the washing-place at Solia, in the marshy ground on one of the streams flowing into Santander harbour. Here the clay is disintegrated by jets of water under pressure from 3-inch hose pipes, and passed through a riddle, which keeps back the larger lumps, the fine stuff and clay going through to the washers. These are cylinders

21 feet 3 inches long, 7 feet 2 inches diameter at the end, with a conical delivery end, supported on friction rollers, and receiving motion by spur gearing. The mixed ore and earth are separated by a constant flow of water; the former is led forward. For this purpose, a spiral angle iron is fixed round the inside of the trommel for half its length, with blades or scoops at intervals to catch the ore and to let it fall down amongst the water every few moments. In the other half of the trommel, the angle irons are spiral in the direction of the length of the trommel, like the rifling of a gun, with blades to catch the ore and let it fall as before. Thus the ore is delivered at one end, while the muddy water flows out at the other, carrying with it a considerable proportion of finely-divided mineral, which is collected by sizing-boxes and current apparatus, and subsequently re-washed, so that only about 5 per cent. is finally lost. The bulk of the washed ore is like gravel in size. The six washing-machines in use turn out about 306 tons of washed ore per ten hours, the yield of the clay being about 21 per cent., exclusive of 40 tons of the stuff which at present escapes. The tailwater is carried by launders to a settling ground in the marsh, where the suspended matters are deposited, and the clean water flows back to the river. The washed ore is conveyed by an extension of the railway of about three miles to the shipping pier at Astillero, at the head of the bay, where there is a depth of 15 feet at low spring tides, and 2000 tons can be loaded in the Bay. The San Salvador Iron Ore Company's mines lie to the east of those of Obregon, the conditions of occurrence being generally similar, but the workings are on the southern slope, which necessitates hauling the stuff to the washing-place across the hill. This is done by an endless chain railway of 18-inch gauge, 2 miles and 66 yards long, divided by angle stations into six sections, the load on the south side being assisted by engine-power through a rise of 345 feet to the summit, and travelling down on the north side 893 feet to the washing-place on the low ground. The washing-plant is somewhat similar to that at Solia, but somewhat smaller About 600 tons of earth is washed at the works at San Salvador per day, producing about 120 tons of ore, with 57 to 59 per cent. of iron. The average yield of the earth is 6 cwt. per cubic yard. The Camargo Mines, worked by Messrs. William Baird & Co., yield a Rubio ore with 50 to 54 per cent. of iron by quarrying as at Bilbao, but about 10 to 15 per cent. of the small stuff is, after preliminary selection and screening, washed in a puddling machine or trough-washer with beater arms, to which the old French

name of *patouillet* is usually given. These ores, unlike those of Bilbao, are products of the alteration of iron pyrites, and not of carbonate of iron; while the pebbles of the ore-bearing clays are probably concretions formed on the spot, and not rolled masses. The composition is shown by the following analysis of a cargo of Obregon ore shipped in June 1895 for the Dowlais Company per ss. *Jane*:—

	Dry.	Moist.
Iron	58·80	55·59
Residue	3·90	3·68
Sulphur	0·073	0·069
Phosphorus	0·028	0·026
Lime	0·50	0·47
Manganese	0·33	0·31
Magnesia	trace	trace

The approximate output of washed ores from the river, adjacent to Santander, was in 1895 about 125,000 tons from Cabarga and 30,000 tons from Camargo, the total export of that year from the port amounting to 203,442 tons. A detailed description of the geological structure of these deposits, and of the method of dressing the iron ore, is given in Mr. Kensington's paper (*Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxvi. 1894, pp. 327–333).

The largest of the groups mentioned above proceeded in launches to Astillero, where Mr. Joseph MacLennan received them. The landing-stage was gaily decorated with flags and flowers, and an effective triumphal arch was erected. Here three special trains were waiting to convey the members to Solia and Obregon, the whole of the route being decorated with numerous Spanish and British flags. The locomotives, too, presented a striking appearance, being entirely covered with floral decorations. At Obregon and Solia the mines and washing-floors were visited, and a sumptuous banquet was served in a wooden pavilion specially erected for the occasion. During the luncheon an excellent guitar orchestra played the British National Anthem and Spanish national airs. At the conclusion eloquent speeches were made by the President, Sir David Dale, by Don Gonzales Trevilla, by Mr. Joseph MacLennan, by the Rector of Solia, an eminent priest of eighty-six years of age, by Don Alberto Palacio, the architect of the bridge at Portugalete, and by the parish priests of Villa Nueva and of the Astillero.

The second group, a party of thirty, left Santander in carriages to visit, by invitation of Messrs. William Baird & Co., the Camargo mines. This party was accompanied by Don Alonso Fernandez Baladron of the

Chamber of Commerce, Don Celestino de la Cagiga and Don José Cabrero Morejon of the Municipal Council, Don Modesto Pineiro, representing the Mining Company, and Don José Gomez. At Camargo the mines and washing-floors were visited, and after having been most hospitably entertained at luncheon, the members returned to Santander.

The third group, numbering also about thirty, proceeded by invitation of the San Salvador Spanish Iron Ore Company, Limited, to Solares, where the washing-floors and mines were inspected under the able guidance of Mr. F. Kensington, the Director. Here, too, lavish hospitality was dispensed, and after luncheon speeches of thanks for the warmth of their welcome were made by Mr. Jeremiah Head and Mr. George Miller, which were gracefully acknowledged by Mr. Kensington.

The fourth group, twenty-four in number, proceeded to the mines of Reocin by invitation of the Real Asturiana Compania. The great distance to be covered rendered an early start necessary.

The first stage, to Torrelavega, was travelled on a new narrow gauge railway going to Cabezon de la Sal, in the direction of the Asturian coalfield. Here they were met by the general manager, Mr. F. Buhse, and other officers of the Company, and drove to the mines at Reocin, about three miles distant. These, like all the other mining enterprises in the district, are open workings on a bed of dolomite, overlying the fossiliferous limestones of Cretaceous age, which extends east and west for about two miles, with a breadth of 120 to 150 yards, with a southerly dip. Where least altered in the deeper parts, this dolomite carries irregular patches of sulphides, galena, blende, and pyrites, which, nearer the surface, have been changed to carbonates of zinc and lead and brown iron ore. The zinc carbonate, which is the most valuable mineral, occurs to some extent in lumps of a spongy texture, which only require calcination in kilns, but mostly as a white earthy mass, intimately mixed with clay, brown iron ore, and other matters, rendering a complicated dressing process necessary before it is fit for smelting. The calamine earth follows the surface of the dolomite, which is extremely irregular, and as it varies considerably in composition as well as in thickness, the workings appear to be of a very unsystematic character, the best guide being the colour of the ground, a whitish tint being taken as indicating the presence of calamine. When this appears, a level is driven into the bank and timbered, rails are laid, and a train of waggons is run in to receive the over-burden, which is stripped and thrown down through a hole in the roof of the level, loaded

into the waggons below, and drawn to the waste tip; the ore stuff, when cleared, going by other waggons to the dressing-floor. The workings are at some height above the valley, so that the ground can be excavated to the full depth of the deposit without pumping. The opening left after the removal of the mineral ground is of a very remarkable character, it being filled with large pillars and tumbled masses of dolomite, in which several shafts and levels, dating back to the period of the Roman occupation, were found in the earlier years of the working.

The dressing-floor, which is connected with the mineral workings by a double line of railway of 3 feet 3 inches gauge, is of very considerable extent, including crushing, sizing, jigging, and sluice-washing plant, driven by a horizontal engine of about 120 horse-power, by Messrs. Tangyes, Ltd. The bulk of the material, however, being of a soft and incoherent nature, the crushers are principally used in the treatment of the harder rock containing sulphides; the calamine stuff requiring only sizing and jigging, while the finer earth goes in great proportion to the slime-washers, which are round buddles, the largest being Linkenbach's pattern, 33 feet in diameter. The finished slimes, however, carry a considerable quantity of brown iron ore, from which they cannot be separated, as the two minerals, limonite and calamine, are nearly of the same density. A proportion of small coal is therefore added to the mixture, which is charged into a reverberatory calciner with two beds, and after drying in the upper one is slowly heated in the lower, the air being so regulated that when the coal is ignited it deoxidises the ferric oxide, which becomes reduced to the state of magnetic oxide. The capacity of the furnace is about six tons a day. The mixture of zinc oxide and magnetite is then passed in a regulated stream over a number of revolving brass cylinders having a portion of their surfaces magnetised by a series of electro-magnets inside. The magnetic particles in falling are attracted from the stream and drawn round on the surface of the cylinder to a hopper placed below, where the contact being broken, the magnetic oxide falls into a separate hutch, while the zinc oxide passes directly into another receptacle.

A certain quantity of an intermediate product is also obtained; this is lifted by an elevator to a pair of crushing rolls, and the ground stuff passes into a Siemens separator, which is similar in principle to that already described, except that the separation takes place inside a rotating cylinder instead of outside, the separated materials being discharged at opposite ends. One material separated is a fairly good iron ore, as shown by the following analysis:—

Ferric oxide	77·88
Ferrous oxide	3·63
Zinc oxide	7·50
Lead oxide	1·17
Manganese oxide	0·80
Sulphur	0·168
Phosphorus	0·016
Silicon	5·073
Alumina	1·416

But the finely divided condition makes it difficult to use, so that 10,000 tons have accumulated since the electric separation was practically introduced. The largest pieces of calamine are burnt in kilns very like ordinary limekilns. The finished material is sent by a metre-gauge railway, five and a half miles long, to the pier at the mouth of the Suances river, on the coast, a few miles west of Torrelavega, whence it is shipped to the Company's smelting works in France and Belgium.

The present annual output is about 15,000 tons, derived from about ten times that quantity of ore stuff and waste excavated. About 600 tons of lead ore are also saved, which go to the Company's works at Renteria, near San Sebastian.

The consumption of water in the dressing operations is very large, about 1300 gallons per minute being required to keep the whole plant at work, and this cannot always be obtained in dry years. A very elaborate system of settling ponds and reservoirs has, therefore, been established on the hillside, about half a mile from the works, where the water rapidly clears and is pumped back.

At the conclusion of the visit to the mines the guests proceeded to Torrelavega, where at the Hotel de Horga an excellent luncheon was served. In proposing toasts, the members expressed their appreciation of the hospitality and kindness they had received from the Real Asturiana Company; toasts which were eloquently acknowledged by the Alcalde of Torrelavega and the Provincial Dèputy of the district, Don Guillermo Ceballos.

The fifth group, consisting chiefly of ladies, numbered about sixty, and proceeded by train to Solares, where carriages were in readiness. The houses in the vicinity of the railway station were decorated with flags, and an artistic triumphal arch had been erected, bearing the inscription, "Welcome." The grotto, which was illuminated with Bengal lights, and the other points of interest were visited, and the beauty of the scenery was much admired. The Com mittee who had organised this excursion, Messrs. Dosal, Fresnedo,

Rodriguez, Tintana, and Corcho, were unremitting in their endeavours to ensure the comfort of their guests. Here again a repast was prepared, with exquisite taste, for the party; and after the banquet Professor Roberts-Austen expressed the President's regrets that he was unable to be present on this excursion, and in a few well-chosen words thanked the Committee for their hearty welcome. Mr. Fresnedo acknowledged, in fluent English, the address of thanks. Having been called upon to say a few words, Lady Dale made an eloquent and touching allusion to the embarkation of troops for Cuba. The Alcalde of Solares, Mr. Casanueva, also gave a brief address.

The groups reunited on the quay to proceed on board the tender for departure to the *Ormuz*, and there the Alcalde of Santander made a brief farewell speech, which was translated by Mr. Fresnedo, and was replied to by the President, Sir David Dale, who expressed his thanks to the people of Santander, to the authorities, the corporations, and the miners for a reception the memory of which would not easily be effaced. On the return of the party to the *Ormuz*, Professor Marcial de Olavarria, of the Madrid School of Mines, presented to the Institute a unique specimen of crystallised martite from the Cabarga Mines of Santander. The presentation was accepted on behalf of the Institute by the President. After this interesting ceremony the Spanish visitors, who had come on board, left the *Ormuz*, which sailed soon after for San Sebastian, arriving there early on Sunday morning, September 6, in magnificent weather. This fashionable watering-place is most picturesquely situated at the foot of the Pyrenees, and the King, the Queen Regent, and Court being in residence, it looked its best. Their Majesties appeared to be much interested in the *Ormuz*, and came out twice in the royal yacht to inspect the huge vessel. The splendid scenery in the vicinity induced the members to make excursions to Irun, Renteria, Tolosa, Pasages, and to Fuentarrabia.

In spite of numerous other attractions, a party of about twenty made an excursion into the country from San Sebastian on September 7th, in order to see some unworked iron ore deposits of considerable size at Cerain. This place is a small village on the eastern spur of the Cantabrian Mountains, about ten miles from Beasain Station on the Northern Railway of Spain. The deposit is mostly included in ten concessions, which have been acquired by Messrs. Griffiths, Tate & Co., of London and Bilbao. A concession in Spain, it may be remarked, is granted to any one who will take up not less than four pertenencias. This term signifies an area of 100 metres square, so that a concession covers

10,000 square metres. Sometimes these grants are taken up so as to leave irregular enclosures of less than this area, and these are then called demasias, and are granted under certain conditions to the adjoining owners. Beasain itself is about 24 miles from San Sebastian, but, for exporting the ore, use would be made of the adjacent port of Pasages, a land-locked harbour with a narrow entrance some three miles nearer France. The ore boldly outcrops on both sides of a mountain 2000 feet in height, and is of somewhat irregular formation. A certain amount of exploratory work has been done, chiefly in the direction of opening up old workings which have been driven into the hillside to follow up veins of galena and blende. Some new shafts, levels, and borings have also been driven in order to gain an approximate idea of the resources, and it is roughly estimated that at least three million tons of ore may be obtained. The ore found, both in the outcrop and in the workings, is the brown limonite, and according to the well-known classification of the ores of Northern Spain into vena, campanil, and rubio, it belongs to the rubio type. Analyses of different samples of the ore from Cerain show :—

Ferric oxide	79·571	78·93	78·30
Oxide of manganese	1·765	1·65	1·82
Alumina	1·479	1·64	...
Lime	0·168	0·17	...
Magnesia	0·468	0·22	...
Silica	5·000	5·20	5·85
Sulphur	0·030	0·10	...
Phosphoric acid	0·033	...	traces
Oxide of lead	0·346	...	...
Oxide of copper	0·038	...	...
Carbonic acid	0·650	trace	...
Combined water	10·350	10·57	8·06
Metallic iron	55·70	55·25	54·80

In order to render this ore deposit accessible, it will be necessary to construct either a wire rope-way or an inclined plane and narrow-gauge railway from the mountain to the station at Beasain. The length of the railway would be about 6 miles, with a fairly uniform gradient in favour of the load down the valleys on either side of the mountain, and its cost would be between £20,000 and £30,000. From the station to the port, with loading and unloading charges, the cost is estimated at under 2s. 6d. a ton, and the total cost of getting the ore from the deposit is taken as about 5s. f.o.b. at Pasages. A few sample loads have been smelted into pig iron with satisfactory results.

On Monday afternoon, September 7th, the *Ormuz* left her anchorage at San Sebastian, and proceeded to the French watering-place of St. Jean de Luz. Tuesday, September 8th, was devoted to visiting Bayonne, Biarritz, and other interesting places in the vicinity, whilst the morning of Wednesday the 9th was, by kind invitation of Mr. A. de Montgolfier, the Director-General of the Compagnie des Hauts-Fourneaux Forges et Acieries de la Marine et des Chemins de Fer, spent in visiting the Forges de l'Adour at Boucau near Bayonne. Carriages were provided to drive the members from the Bayonne Railway Station to the works, and the party was conducted round the works by Mr. Magnin, the Director, Mr. Detanger, the Assistant-Director, and the staff of engineers, all of whom spared no pains in giving explanation upon all points when such information was desired. The excursion was well attended, and was in every way a most agreeable one. The particulars of these works are given in the accompanying notes on the works visited.

On the return of the party to St. Jean de Luz, it was found that the weather no longer gave any promise of allowing the ship to stay till the following day, and, consequently, the *Ormuz* left the bay at 7.30 P.M. on Wednesday, meeting the threatened sea disturbance a few hours later. This, however, did not prevent her safe arrival at the Nore in forty-eight hours. The landing was effected at Tilbury by 9.30 A.M. on Saturday, and about an hour later the whole party dispersed in London, carrying away with them the recollections of a thoroughly successful and in every way enjoyable meeting.

Reports of the excursions have been published in the *Engineer*, vol. lxxxii. pp. 258, 283, 312, and 349 (which have been largely drawn upon in the preparation of this report); in *Engineering*, vol. lxii. pp. 333–336; *Ironmonger*, vol. lxxvi. (extra number); *Iron and Coal Trades Review*, vol. liii. pp. 387–389; *Iron and Steel Trades Journal*, vol. lix. pp. 341, 347; *Contract Journal*, vol. xxxv. pp. 495, 547; *Colliery Guardian*, vol. lxxii. p. 691; *Stahl und Eisen*, 1896, No. 19 (by Dr. H. Wedding).

NOTES ON WORKS VISITED.

The Railways of Biscay.

The province of Biscay has an area of 2198 square kilometres, and, according to the last census, a population of 234,880, or 67 inhabitants per square mile.

It is traversed by the various railways of which particulars are given in the following table:—

	Length in Kilometres.						
	In the Province.			Outside the Province.			Total.
	Of 1·67 metre gauge.	Of 1 metre gauge.	Total.	Of 1·67 metre gauge.	Of 1 metre gauge.	Total.	
Tudela to Bilbao	26·000	...	26·000	223·037	...	223·037	249·037
Bilbao to Portugalete	11·892	...	11·892	...	...	...	11·892
Cantalojas to Olaveaga	2·160	...	2·160	...	...	...	2·160
Desierto to Memerea	12·372	...	12·372	...	...	...	12·372
Bilbao to Durango	...	32·723	32·723	...	...	...	32·723
Durango to Zumárraga	...	17·000	17·000	...	35·148	35·148	52·148
Amorebieta to Guernica	...	14·531	14·531	...	...	...	14·531
Guernica to Pedernales	...	9·475	9·475	...	...	...	9·475
Bilbao to Las Arenas	...	11·461	11·461	...	...	..	11·461
Luchana to Munguia	...	16·248	16·248	...	...	...	16·248
Las Arenas to Plencia	...	14·184	14·184	...	...	...	14·184
Bilbao to Lezama	...	15·035	15·035	...	...	...	15·035
Zorroza to Valmaseda	...	27·863	27·863	...	...	...	27·863
Zalla to Solares	...	32·000	32·000	...	49·167	49·167	81·167
Valmaseda to La Robla	...	4·000	4·000	...	279·912	279·912	283·912
Galdames to Sestao	...	21·037	21·037	...	...	...	21·037
Luchana to El Regato	...	10·000	10·000	...	...	...	10·000
Orconera to Luchana	...	13·800	13·800	...	...	...	13·800
Franco-Belgian Company	...	7·828	7·828	...	...	...	7·828
Total	52·424	247·185	299·609	223·037	364·227	587·264	886·873

The last four include 52·665 kilometres of mineral lines.

From this table it will be seen that there are 886·873 kilometres of railway which can be considered as appertaining to the province, and of these 299·609 are inside and 587·264 outside the boundary. Taking the 299·609 kilometres, there are thus 133 metres of railway per square kilometre, and 1·24 metre per head of population.

Railway from Bilbao to Portugalete.

This railway, which has the normal gauge and lies on the left bank of the river Nervion, was opened to traffic on March 19, 1888, with a single line. The double line of rails between Bilbao and Luchana was opened in 1892. The total length is 12 kilometres (7½ miles), and there are seven stations—Bilbao, Olaveaga, Zorroza, Luchana, Desierto, Sestao, and Portugalete. The station at Bilbao is in the most densely populated part of the town, and is connected with the Northern Railway. Within the first kilometre the line passes by the maritime belt of Uribitarte, where the Custom House is established. In the second kilometre it passes the locomotive sheds, shops, and stores of the Company, and in the third the foundry of Messrs. Averly & Co. From the station at Olaveaga, at a distance of 4 kilometres, a line branches off to Cantalojas on the Northern Railway, and is intended exclusively for mineral traffic, principally iron ore from Ollargan, of which from three to four hundred thousand tons are carried yearly to the stock piles, which are placed about a kilometre from the station. At Zorroza station (6 kilometres) there is a junction with the narrow-gauge lines from Zorroza to Valmaseda, from Valmaseda to La Robla, and from Bilbao to Santander, and at 5·8 kilometres from the starting-point, the river Cadagua, the limit of the jurisdiction of Bilbao, is crossed by a 65-metre iron bridge. At Luchana (7 kilometres) it joins the mineral line of the Orconera Iron Ore Company, and after passing below the similar lines of the Luchana Mining Company, and those of the Franco-Belge Company, it has a branch line for the iron and steel works of Altos Hornos, which joins at the eighth and ninth kilometres the main single line as far as the station of El Desierto, after having passed through a short tunnel of 121 metres. At the last station the line joins the Triano normal-gauge railway, the property of the Provincial Deputation of Bilbao, which ends at San Julian de Musques. At Sestao (10 kilometres), after crossing the river Galindo by a bridge of 40 metres span, and passing through a tunnel of 101 metres in length,

the line passes the Aurrera Foundry and the Viscaya Steelworks, for which there is a special branch. The line, at first level, and then dipping under the mineral line from Galdames, arrives at Portugalete, to which seaside resort summer visitors and tourists of all classes come in large numbers.

Central Railway of Biscay.

The line from Bilbao to Durango is 33 kilometres long. At Ariz there is a branch line of 2 kilometres to Dos Caminos, connecting with the Northern Railway. The railway began working on June 1, 1882, with 4 locomotives, 29 small coaches, and 22 waggons. There are now 7 locomotives, 12 bogies, 40 coaches, and 190 waggons. At Amorebieta the line joins that from Amorebieta to Guernica and Pedernales, and at Durango that from Durango to Zumarraga. In the year 1895 there were carried 380,329 passengers and 88,626,798 kilogrammes of merchandise, the receipts being 826,016 pesetas, the expenditure 296,711 pesetas, and the profit 527,305 pesetas. No accident has ever occurred on this line.

Light Railway from Bilbao to Las Arenas.

The light railway from Bilbao to Las Arenas has a length of 12 kilometres (7½ miles). It was built in 1886–87, and opened on July 1, 1887. It is the only line in the country on which metal sleepers are used. The passenger vehicles are on the American system, with a central gangway in the second and third classes, and a corridor at the side in the first-class carriages. There are five stations—Bilbao, Deusto, Luchana, El Desierto, and Las Arenas—and the line is connected with the other railways of Luchana and Las Arenas, of 15 and 17 kilometres respectively. That from Luchana to Munguia and that from Las Arenas to Plencia, are both worked by separate companies. At present there are running 46 trains daily, which start from the termini at 5.20 A.M., at 6, 7, 8, and from that hour every forty minutes up to 8 o'clock in the evening. The last train starts at 9 o'clock. During the year 1895 there were carried 640,838 passengers and about 29,000 tons of freight. The total receipts were 220,000 pesetas.

The Biscay Bridge.

At the mouth of the river Nervion, which runs up to Bilbao, there has been erected a graceful iron bridge, the only one of its kind,

designed and built by the Spanish architect Don Alberto de Palacio. Strictly speaking, it is not a bridge, but should rather be called a conveyor, as it consists of a single moving platform which runs from one bank to the other, on a plan which the inventor has patented. This bridge has been given the form of a huge triumphal arch bridging the space between the banks, so that vessels can pass freely under it as they proceed up the river to the port of Bilbao. The total length between the cable anchorages is a little less than half a kilometre. The total weight of the metal-work of the structure is approximately 600 tons. The strain of the cable is 2000 tons, and the load on the foundations of the piers amounts to 1000 tons. On the lower part of the platform there are two parallel ways 25 centimetres wide, with rails weighing 10 kilogrammes, the distance from one way to the other being 8·20 metres. The carrying platform is 48 square metres in area. The total weight carried by the bridge is 40 tons, of which 12 tons is the dead load of the platform, and 28 tons the live load carried. For working the platform there is a compound steam-engine of 25 horse-power, but as a rule not more than 7 horse-power is required.

The Altos Hornos Company.

This Company was founded December 2, 1882, with a capital of 12,500,000 pesetas, divided into 25,000 shares of 500 pesetas. The works "Carmen" at Baracaldo, and those named "Merced" at Guriezo in the province of Santander, started by Messrs. Ibarra & Co., formed the basis on which the present Company was floated.

The following description is restricted to the Carmen Works, which are situated between the rivers Nervion and Galindo, and cover an area of approximately a million square feet.

They are devoted to:—

The manufacture of the best brands of wrought iron. The production of pig iron for the manufacture of tubes, and also for the manufacture of Bessemer pig. There are four blowing-engines, three vertical and one horizontal, for the four blast-furnaces, which have a capacity of 300 tons daily. The aggregate horse-power of the engines is 1500. The stoves for heating the blast are on the Cowper system in those last erected, whilst the older ones are pipe stoves. The blast-furnace gases, besides heating the stoves, are also used for firing 27 boilers rated at 3000 horse-power.

In the old buildings are placed 15 puddling furnaces with three

hammers and the cogging-mill. There are also four plate-mills, which are served by eight reheating furnaces. Close by is a hot saw and three cold shears, one of which is double.

For the manufacture of Bessemer steel there are two converters, each capable of converting 9 to 10 tons at a blow, and on the average 15 blows are made daily.

The open-hearth furnace of 12 tons capacity has made as many as 20 heats in the week.

In the steel rolling-mills there are three reheating furnaces and two open-hearth furnaces, with Wilson producers.

The mills are driven by two reversing engines, one of 2000 and the other of 8000 horse-power.

The average out-turn of these works, when in regular work, is as follows:—100,000 tons of pig iron; 12,000 tons of puddled iron; 15,000 tons of steel of varying section; 6000 tons of plates; 45,000 tons of rails and bars; 6000 tons of castings; 3000 tons of bridges, roofs, and boilers; 1000 tons of machinery.

About 3000 men are employed in these works.

The Vizcaya Works.

Number of workpeople in the works, 1850; number of workpeople at the mines, 500; area of the works, 50 hectares, or 123·5 acres; length of railway inside the works, 12 kilometres (7½ miles); horse-power of the engines, 4000; annual consumption of ore, 250,000 tons; production of coke, 100,000 tons; production of pig iron, 120,000 tons; production of iron and steel plates, 50,000 tons.

The plant comprises:—3 blast-furnaces, with 12 modified Whitwell stoves and 3 Cowper stoves; 3 blowing-engines, 2 Cockerill and 1 Bayenthal; 144 Simon-Carvés coke ovens, adapted for the recovery of by products; 4 open-hearth furnaces; 4 Robert converters, 2 working and 2 under repair; 4 single puddling furnaces; 2 gas-fired double furnaces; and rolling-mill, in which are made girders, rails, round, square, and angle iron, hoop iron, wire rod, &c.

The Iberia Tin-Plate Works.

The Iberia Company began the manufacture of tin-plates in 1889 with two rolling-mills. In 1894 it had in operation six rolling-mills, a number which has been recently reduced to four, owing to the inauguration of a second tin-plate works in the district. The

Iberia Company possesses a department for the lithographic decoration of tin-plate, another for the cutting and stamping of various articles, and a third for the manufacture of galvanised iron pails. It also has an iron and bronze foundry. There are five Belleville boilers of 200 horse-power. The engines driving the mills are four in number, compound condensing, yielding 300, 260, 160, and 160 horse-power respectively. There are also four other smaller engines. The number of workpeople of both sexes amounts to 400. The works cover an area of 12,000 square metres, and the capital of the Company is 2,500,000 pesetas.

The Basconia Tin-Plate Works.

The Basconia Tin-plate Works are situated at San Miguel de Basauri, in the province of Biscay, at a distance 3 miles from Bilbao, and 500 metres from the station of Dos Caminos on the line from Tudela to Bilbao. The Basconia Company, Limited, was founded in December 1892. Its works cover an area of 16,535 square metres, of which 4607 are roofed in. The chief departments are: (*a*) The boiler-house, with four Babcock & Wilcox boilers, an economiser, and a chimney 43 metres in height. (*b*) The plate-mills, with three hot finishing trains of rolls, and another in course of erection. Two of these are driven by a vertical condensing engine of 300 horse-power, and a third by a Jouval turbine of 120 horse-power. In this building are placed the shearing machines and the tables for separating the plates. (*c*) The pickling department, in which the plates are moved up and down in the bath by a single acting, vertical, non-condensing engine of 6 horse-power. The plates are only lifted by the engine and fall by gravity. (*d*) The annealing department, with an ordinary furnace and a chimney 17½ metres high. (*e*) The cold mill, with four pairs of rolls driven by a 60 horse-power Jouval turbine. (*f*) The tinning department, with eight English and one French sets driven by a horizontal non-condensing engine of 15 horse-power. In this building are eight machines for removing grease, and three brushing machines, and farther on are the sorting and packing rooms and the store. (*g*) The tin and grease refinery, with one boiler for treating grease, and one furnace for extracting tin from the slags. Adjoining this is a building for making green vitriol. (*h*) The carpenters' shop, with a circular saw, a band saw, and other necessary tools. In this building is also placed the machine for branding the boxes. (*i*) The fitting shop, with the necessary tools, and also including two brushing machines, a radial

drill, hand drill, four lathes, fan for the forge, punching machine, and shears. There is also a non-condensing horizontal steam-engine of 20 horse-power, which has not been used, as the machinery in these last two shops is driven by a 7 horse-power electric motor. (*j*) A smithy, with two forges, hammers, portable forge, &c. (*k*) Electric light is supplied by a dynamo driven by a 30 horse-power turbine. This dynamo also supplies current to a motor in the tinning house. There is also a small steam-engine for the shearing machine, and a locomotive running between the works and the station. A 13 horse-power electric motor is now in course of erection to drive the machinery in the tinning house, the current being supplied by the 30 horse-power turbine mentioned above, driving the dynamo so arranged as to give 24 horse-power for lifting, and 16 horse-power for motive power. The ordinary out-turn of tinplate is 310 boxes daily, and this product is not further treated at the works. The number of workmen employed is 200.

Tube Works at Bilbao.

The Limited Company "Tubos Forjados," at Bilbao, was founded December 2, 1892. Its works, devoted to the manufacture of iron and mild steel tubes, are situated in the district of Elorieta, jurisdiction of Deusto, approximately half-way between Bilbao and Las Arenas. The building of the works was begun in March 1893. Steam was first admitted on February 19, 1894, into the cylinders of the steam-engine, which is a double expansion tandem engine of 250 horse-power, and the works were in full operation in the middle of April. They cover an area of about 8700 square metres, and consist of four shops and two buildings. The former are the fitting-shops, the factory, the erecting shop, and the galvanising house. In the fitting shop (28 by 8 metres) are placed the steam-engine with its surface condenser, and also other machinery, which is principally used for repairing work. A dynamo is also placed here for supplying current to six arc lamps and some 950 incandescent lamps. In addition there is also some machinery for making tube fittings.

In the factory there are five furnaces, seven drawing benches, and one rolling-mill. Three of the drawing benches and the mill are used for making lap-welded boiler tubes, being devoted to levelling, bending, and rounding the skelps. For the manufacture of butt-welded steam and water pipes a double bench has been built, with the corresponding bending and straightening appliances. For making bedstead tubes

there is a simple bench for making welded tubes, and another for drawing open-jointed tubes. The five furnaces are used, one for bending, one for welding boiler tubes, one for water and gas piping, and one for each kind of bedstead tubes. Steam is generated in four multitubular boilers, two Büttner boilers of 110 horse-power, and two Babcock & Wilcox boilers with 75 and 50 square metres of heating surface respectively. Waste gases from the furnaces are used for heating all these boilers, except one which is fired directly, and is only used as a reserve when the furnaces are not at work. The finishing shop, 16 by 48 metres, contains all the machinery for finishing the tubes and fittings: there are six screwing machines, two testing machines, one a hydraulic press working up to 150 atmospheres, and the other a steam machine working to 8 atmospheres; three flange dressing machines; two pipe-cutting machines; one roll lathe; one bedstead tube polishing machine; one machine for making unions; machines for grinding, polishing, &c. Behind the building erected for making the tubes, which is 30 by 48 metres, there have been put up seven sheds, of which four cover the boilers, one contains presses for doubling and bending, and the others contain forges and furnaces for welding on the small rods which serve as handles in manufacturing the tubes. In the galvanising shop, which is 8 by 28 metres, is situated the plant for cleaning, drying, coating, and cooling, and also the machinery for scouring.

Two buildings that have been mentioned as principal ones are, one used as a storehouse, 24 metres square, in which are stored the stock of tubes and rods that are used for the manufacture of bedsteads. The metal for the other classes of tube are placed in the open before this storehouse. The other building has three storeys: the ground floor is used to store tube fittings in racks with 650 divisions, and it is also used for the preparation of orders intended for sale. The first floor is used as offices and the directors' apartments, and the second floor is used for the books and sample rooms. In the factory about 2000 metres of 0·60 metre gauge line has been laid down. Numerous turn-tables and branches allow the whole of the works to be served very effectually. The rolling-stock consists of twenty trucks, of which eight are of a type specially designed to carry tubes and metal. The tram lines run through the storerooms, and out in front of the factory on to a wharf belonging to the Company, where their own barges can lie alongside to be loaded with tubes, or to have the raw material unloaded. Material may also, however, be transported by the electric tramway, and the railway from Bilbao to Las Arenas is utilised to a certain extent.

By working day and night the works could produce 3000 to 3500 tons of tubes annually. Up to the present time this out-turn has not been obtained because of the lack of orders, but the trade has increased steadily and rapidly. In the first year the monthly sales were 68 tons, in the second year 100 tons, and at the present time, the third year, the amount has increased to 130 tons on the average. The number of workmen has increased in like manner. When the works started 75 men were employed, and now 150 are engaged, of whom about a quarter are boys and lads from 12 to 18 years old. Most of the work-people live in the neighbourhood, but there are ample facilities for reaching the works for those who live farther afield. The raw materials employed, chiefly iron and coal, are obtained from the different works and mines in the northern provinces of Spain. The application of tubes has been watched carefully by the Company, which has extended its operations to making coils, tubular posts, balustrading, &c., as well as steam and hot water radiators. Of all these applications, especial mention should be made of the posts made for supporting the conductors on the electric lines from Bilbao to Las Arenas and from Bilbao to Santurce.

THE DEUSTO WORKS.

These works, for the manufacture of cast steel by the Robert process, belong to a limited company founded in 1891 with a capital of 1,000,000 pesetas. They are situated on the right bank of the river Nervion, a short distance from Bilbao, on the road to Las Arenas, and cover an area of 12,000 square metres. The various sections of the works are as follows:—The converter department, in which castings from a few ounces up to ten tons each are made; foundry, &c.; forge; fitting shops, with the necessary tools for finishing all the various products manufactured; offices, storerooms, &c. Two hundred workmen are employed, and the annual production amounts to 700 to 800 tons, principally wheels and axles and accessories for railway waggons, and complete waggons, permanent way, machine tools; ships' stems, stern-posts, and propellers; rolls, &c., for rolling-mills; presses of all kinds; and, in fact, machinery of all kinds in which cast steel can be used. By the Roberts process steel of excellent quality can be made, and of all grades from extra soft up to the hardest that is required in the very numerous applications of cast steel.

Santa Ana de Bolueta.

These works are situated on the banks of the Nervion, some three kilometres (two miles) above Bilbao, in proximity to the rich mines of Ollargan, which are partly under the same control. They are devoted to the manufacture of charcoal pig iron of superior quality, and their products are held in such high esteem that more than once they have been exported to England and Belgium in competition with Swedish iron. At its foundation, which dates back to 1842, these works created in Biscay a revolution in the iron industry. At that time iron was only worked in what is known as the Catalan forge, but which ought to be named the Biscay forge, after the most important centre of this patriarchal industry, which was formerly so extensively worked in that district, and of which there can now be found but the scantiest trace.

At Bolueta were established the first blast-furnaces and the first rolling-mill in Biscay, and the works still preserve the first bar of iron made in the country by this system. In 1873 these works were the first to introduce the regenerative system of heating puddling-furnaces, and they also took the initiative in Spain of introducing the manufacture of steel on the neutral hearth.

Little more than a year ago this enterprising company erected a blast-furnace on new lines and of larger dimensions than had previously been used. They have also built a quadruple puddling-furnace, similar to those used in Styria, and to follow up the work of improvement, the antique water-wheels are to be replaced by improved horizontal flow turbines, which drive the rolling-mills direct through belting, instead of by the previous heavy and complicated gearing.

Finally, with the object of utilising conveniently the surplus hydraulic power available during the greater part of the year, there is now being laid down an important electric installation for supplying Bilbao and its vicinity with light and power.

The works at the present time possess, in addition to the new furnace mentioned above, three old-fashioned blast-furnaces, of which some will shortly be taken down. In addition there is the quadruple puddling-furnace with its producer, and another puddling-furnace fired with gas from the blast-furnace. There are also five ordinary hand-fired puddling-furnaces and two regenerative furnaces fired with blast-furnace gas, together with two furnaces of the ordinary type. The mechanical appliances consist of:—Two blowing machines for the blast-furnaces; a hammer and a rolling-mill for puddled bar; a large plate rolling-mill;

a small plate-mill. All the motors up to 200 horse-power are hydraulic, and consist of four waterwheels and an old turbine; but, as has been said before, these are to be replaced by modern turbines. A steam-engine is to be held in reserve in case water fails. The establishment also possesses a foundry and workshop. It covers 2½ hectares (6 acres), and employs 200 hands.

Wrought Iron Works of La Purisima Concepcion de Astepe.

These works, founded in 1856, are the property of the firm of Messrs. Juan J. de Jauregui's Sons. They are situated on the right bank of the river Ibaizabal, in Amorebieta, Zornoza. The following statement gives some particulars of these works: Situation—On the Central Biscay Railway; fall of water, 5 metres. Hydraulic power—100 horse-power from two turbines. Steam power—50 horse-power from three boilers and one engine. Workmen, 170. Blast-furnace—One charcoal blast-furnace. The ores are melted without limestone, which is unique in Spain. Cementing-furnace — One of 30 tons capacity. Puddling-furnaces — Four, two for blast-furnace gas, and two with grates. Refinery—One. Hammers—Three, two for forging with a producer furnace, and one for blooms. Rolling-mills — Three, the larger hydraulic, the two others by gas. Foundry and engineering shop for repairs. Coke ovens and slag heaps, occupying an area of 12,000 square metres. Other properties, adjacent to the works, are the chapel, offices, and houses for the workmen, &c., &c.

The Zorroza Engineering Works.

This Limited Company was founded in 1892, and has a capital of 1,000,000 pesetas. The works are situated in the confluence of the Cadagua, and are devoted chiefly to the construction of ships, bridges, roofs, boilers, as well as general machinery and foundry work. Two hundred men are employed, and power is supplied by an engine of 40 brake horse-power. The establishment covers about 11,000 square metres, on which there are three chief buildings and several annexes. The machinery and tools are of the kind usually employed in this class of work. They include shearing, punching, and drilling machines, and hydraulic riveters for shipbuilding; lathes, planing, and drilling machines, &c., for machinery work generally. The average production is 2000 tons yearly, and the following objects, which have been made at these works, are to be seen in Bilbao: Bridges—The swing bridges

of S. Agustin and the platform of the Viscaya bridge; Roofs—The Euskalduna tennis-court, and paper-works at Cadagua; Machinery—Much of the plant in the most important works in the district.

Foundries of Messrs. Averly & Co.

These works, which cover an area of 11,000 square metres, are situated in the plain of San Mamés, crossed by the railway from Bilbao to Portugalete. Some of the trains on this line stop near the works at a special platform. The number of workmen employed in the foundry, forge, fitting shop, and boiler shop is about 120, and amongst the work turned out are iron and other castings, boilers, turbines, bed-plates, sleepers, and other railway material, tanks, roofs, agricultural machinery, such as wine-presses, ploughs, &c., confectioners' plant, troughs, cylinders, &c. The workshops are provided with the best of modern machinery, driven by two engines, one a compound Averly-Brown engine, compounded on the Averly system, and the other a 50 horse-power engine. Although these works were started by Don Antonio Averly y de Fraragoze only ten years ago, the estimation in which they are held is high, and the number of their customers is fairly large.

The Aurrera Company's Works.

The manufactures of these works comprise iron pipes and accessories of 40 to 400 centimetres diameter for water, gas, and steam pipes; ordinary castings of iron, Piat steel and bronze; and Decauville waggons and portable railways. At the present time 80 workmen are employed. The motive-power is steam, 140 horse-power, and the area covered by the works amounts to 22,500 square metres.

The Vizcaina Glassworks.

These works are situated in the plain of Lamiaco, jurisdiction of Lejona, 12 kilometres ($7\frac{1}{2}$ miles) from Bilbao. They cover an area of 40,332 square metres. The original company was founded September 13, 1890. There are three buildings—one for the factory itself, one for the offices, and one for lodging the workpeople.

The factory consists of a building with a roof of three spans on the English system. Under one span is a tank furnace of the Gobbe type, with eight working places. The part under the central span is divided into sections for the mixing department; the furnaces for preparation

of the refractory materials; the stores for chalk, sulphate of soda, sand, refractory materials; the washing room, the carpenters' shop, box room, blacksmiths' shop, engine room, and grinding mill room. A line of rails in front of these departments gives access to the trucks brought by the tramway from Bilbao and the trucks used in the works. At the end of this part of the building is placed the clay works for making all the refractory products. This building has a ground floor and two stories, in which are placed the furnaces and corresponding kilns. On the left of the tank furnace, and within the central building, are placed the flatting ovens, to the number of five, occupying a large hall of 1600 square metres. At the extreme north of this department are the stores of window glass, built in two stories with double T iron. The third section or gallery of the building runs parallel with the central building for 200 metres, and has a width of 15 metres. The roof consists of iron arches covered with corrugated galvanised plates, and supported on cast-iron columns. This building is used for a coal store, a shop for cutting glass, which is a large hall 60 by 12 metres, and a packing room. The central part contains five gas-producers, which generate the gas used for casting glass as well as for the De Nayer boilers for driving the shafting. In front of this gallery runs the tram line which connects the entrance of the works with the tramway and the railway from Las Arenas. Inside this building, as in the others, there are Decauville narrow guage lines for serving all the departments.

The workmen's buildings have an area of 900 square metres, cellars, the ground floor, and three stories. The cellars are used as a wood and iron store. The ground floor contains general storerooms, chemical laboratory, dispensary, living rooms for single men, kitchens and dining-rooms. The three upper stories are entirely used as flats, each with 72 rooms, or 216 in all. In the upper part of the building are placed two large tanks for supplying water.

The offices are situated on the high-road from Bilbao to Las Arenas, in front of the dam constructed for the works. They consist of cellars, ground floor, and two upper stories. The ground floor is divided into two equal parts by the vestibule through which the railway lines pass, and where the weighing machine is placed. The offices are placed on the right, and on the left are the telephone, weighing room, porter's lodge, &c. On the first floor are three rooms for the managing staff and records, and on the other floors are the clerks and managers of the works.

The motive power aggregates 45 horse-power, including the electric light machinery. The production amounts to 2000 square metres of sheet glass of all kinds, sizes, and thicknesses made by blowing. The number of workmen is 372.

The Vizcaina Paper Works near Bilbao.

A limited society founded in 1890, this company possesses works at Arrigorriaga, a small Biscayan town, nine miles from Bilbao, on the Northern Railway. The motive power at the works is derived from five Galloway boilers, rated at 1250 horse-power, eight steam-engines of an aggregate of 840 horse-power, and two turbines giving 300 horse-power. Besides the requisite amount of machinery for making pulp, there are five paper-making machines. Four of these are on the continuous system, two making cigarette-paper and two for printing-paper. The works supply the Arrendatana Tobacco Company with paper for smoking, and for wrappers, both printed and unprinted. They have large printing, lithographing, and electrotyping departments, and have erected buildings for the preparation of all kinds of wall-paper. Some 400 workpeople are employed, and the daily out-turn of different kinds of paper is ten tons.

Cadagua Paper Works.

This Limited Company has two works. The old works, named La Carolina, are confined to the manufacture of cigarette paper, and employ fifty-five workmen. The other works, "La Conchita," produce daily ten or twelve tons of paper for printing, writing-paper, &c. There are two turbines, a 250 horse-power steam-engine, two 40 horse-power engines, one of 12, and one of 10, together with three dynamos for the electric light. Two hundred workmen are employed.

Delta Español.

This Limited Company is devoted to the manufacture of all kinds of metallic alloys, Delta metal, bronze, brass, &c. Sixty workmen are employed. The works are divided into three departments: the foundry, fitting, and rolling shops. The foundry is equipped with twelve crucible furnaces, one reverberatory furnace, and one cupola.

THE ADOUR WORKS.

Origin of the Works.—The Adour Works were established in 1882–83 when the Midi Railway Company relaid their lines with steel rails. At that time the lowering of the customs duties did not permit further manufacture of rails in the centre of France—at St. Chamond, for instance, where the headquarters and one of the principal works of the Company were situated. The erection of works on the coast had for its object the utilisation of English coal and Bilbao ores, which allowed the cost of production to be considerably lowered.

Geographical Position.—These works lie near Bayonne, on the mouth of the Adour, with a port on the river and sidings connected with the line of the Midi Railway Company. This situation allows them to receive ores from Bilbao and from the north of Spain, from Bidassoa and the French Pyrenees, from Arriège, &c., and also English coal from Cardiff, Newport, Newcastle, &c. The products are sent away by railway or by sea.

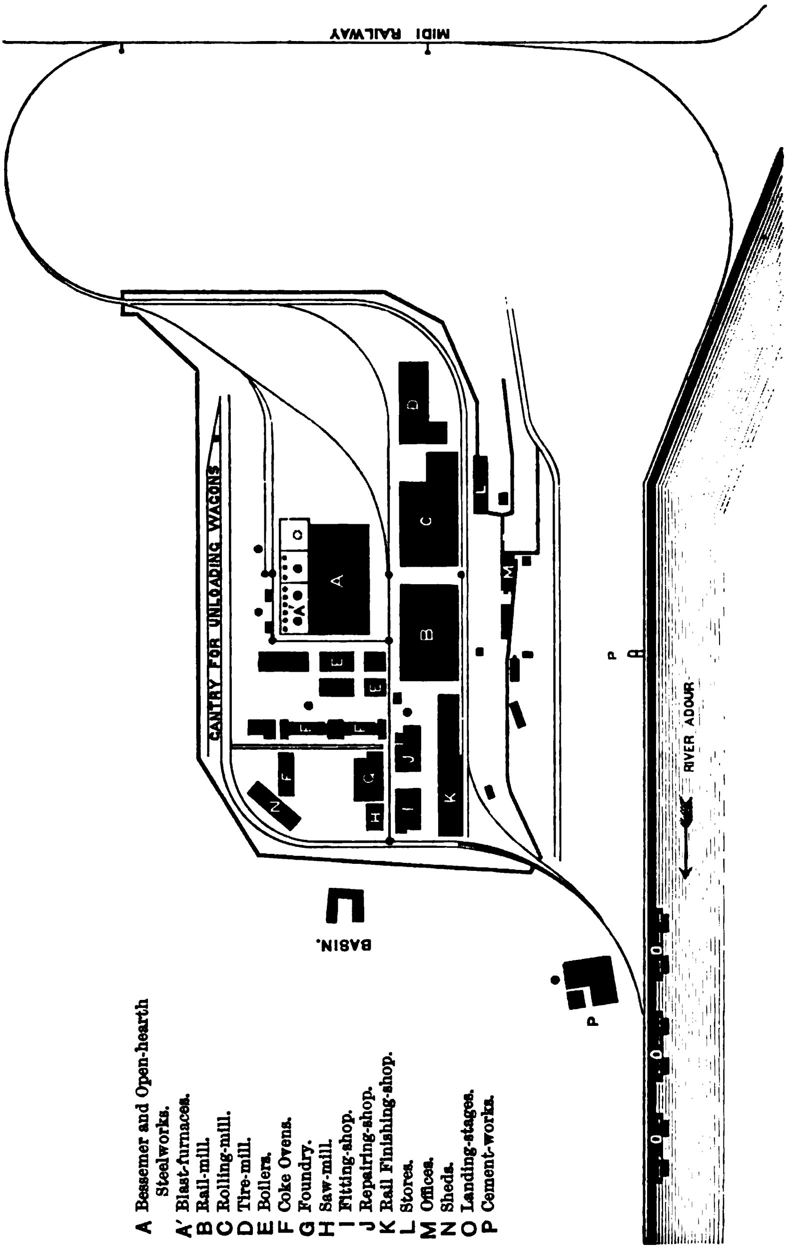
Cranes for Loading and Unloading.—There are three landing-stages, where boats drawing 19½ feet can easily lie alongside. On each wharf are three steam cranes, and 1500 to 2000 tons can be discharged in twenty-four hours.

Gantries.—Raw materials are carried on a normal gauge railway to three parallel gantries or viaducts, 820 feet long and 19½ feet high, built on iron columns over the storage bins.

Coke Ovens.—The works make their own coke for supplying the blast-furnaces, and the plant includes crushing and mixing appliances, with three bins, screw conveyers, elevators, &c., driven by a 100 horse-power engine. The crushed coal is elevated into a bin of 200 tons capacity. There are six batteries of 118 Coppée or Bernard Siebel ovens. Small coal from Cardiff with 18 to 20 per cent. of volatile matter is coked in these ovens in twenty-four hours. Each oven is 17¾ inches wide, 4 to 4½ feet high, and 29½ feet long. The charge is three tons of coal, and the production is about 2·3 tons per oven. A Belleville multitubular boiler is annexed to each battery to utilise the waste heat, and 1200 horse-power is thus obtained, which drives the rolling-mills. This application of multitubular boilers to coke ovens is the first of its kind on the Continent.

Blast-Furnaces.—There are three furnaces in blast and one building. They are 62 feet in height, 17 feet in diameter at the

PLAN OF THE ADOUR WORKS.



A Bessemer and Open-hearth Steelworks.
A′ Blast-furnaces.
B Rail-mill.
C Rolling-mill.
D Tire-mill.
E Boilers.
F Coke Ovens.
G Foundry.
H Saw-mill.
I Fitting-shop.
J Repairing-shop.
K Rail Finishing-shop.
L Stores.
M Offices.
N Sheds.
O Landing-stages.
P Cement-works.

boshes, 6½ feet in the hearth, and 11½ feet at the throat, and the capacity is 7063 cubic feet. They are served by two hydraulic lifts. The blast is heated to 700° C. in nine Cowper stoves, which are 21 feet in diameter, 59½ feet high, and have two stacks 180 feet high, and 7¼ feet internal diameter at the top. The blast-furnaces, hot blast stoves, lifts, charging floors, and pig beds are arranged in parallel lines.

The blast-furnace slags are used as road metal and as filling. Some of the slag is granulated by running it into cold water as it is tapped from the furnace, and is then manufactured into slag cement at a cement works annexed to these works.

The blast-furnaces have a cup and cone, and two side gas take-offs for gas. The daily production amounts to 75 to 80 tons of pig iron per furnace, Bessemer and open-hearth pig iron, and also iron suitable for cannon, armour plate, and projectiles, being made for the St. Chamond Works.

Special Manufactures.—For the last ten years the Adour Works have made special alloys of iron containing chromium, tungsten, and nickel. Amongst these are ferro-chromium containing 50 to 70 per cent. of chromium, ferro-tungsten with 75 to 85 per cent. of tungsten, and ferro-nickel with 92 to 95 per cent. of nickel. It is believed that there are no other works ordinarily making these products, which are so largely sought after not only in France, but also in England, Germany, America, and elsewhere. Since the visit paid to these works by the members of the Iron and Steel Institute on September 9, 1896, two samples of ferro-chromium have been submitted to Dr. S. Rideal, who analysed them by the process perfected by himself and Dr. Rosenblum. The results obtained showed that these samples contained respectively 63·0 and 69·5 per cent. of chromium. These alloys are intended for the manufacture of steel of high tensile strength, such as is used by the naval and military authorities for projectiles, armour plate, &c. The ores used are obtained from Asia Minor, New Caledonia, and Canada.

Bessemer and Open-Hearth Steel Works.—Steel is made in a building placed parallel to the blast-furnaces. There are two casting pits with three 7- or 8-ton converters receiving metal direct from the blast-furnaces, and two open-hearth furnaces of 12 to 15 tons capacity. These furnaces are basic lined, and they treat hæmatite iron and scrap from the rolling-mills, &c. Bessemer steel is used for making rails and girders; open-hearth steel for tires and for section iron used for

shipbuilding. The mild steels made take the place of the best brands of Swedish and Lancashire iron.

Machinery for the Blast-Furnaces and Steel-Works.—This includes:—(*a*) Three blowing-engines of the Cockerill type for the blast-furnaces. The air cylinder has a diameter of 9·84 feet and a stroke of 8 feet. They run at 12 strokes per minute, take 300 horse-power, and give 14,833 cubic feet of blast at a pressure of 9·84 inches of mercury. (*b*) Four double tandem compound blowing-engines, each with an air cylinder 3·28 feet in diameter and 4·98 feet stroke. They run at 40 strokes per minute, and absorb 650 horse-power. (*c*) Four pumps for the hydraulic accumulators which serve the steel-works and rolling-mills, and also some subsidiary pumps. Four pumps supplying water to the works for the tuyeres, and also for the lifts. Each pump can give 880,000 gallons in twenty-four hours. (*d*) An electric generating station, using 250 horse-power, for generating a current of 110 volts. Power is transmitted to pumps placed at a distance on the river-bank, and lifting 4,400,000 gallons in twenty-four hours. The current is also used in the workshops and for lighting the wharves, railways, and the various buildings.

Steam Power.—Steam is generated for this plant by fifteen boilers, of which eight are fired by blast-furnace gas. These boilers are cylindrical, with a length of 55¾ feet, diameter 3¼ feet, and a heating surface of 1098 square feet.

Rolling-Mills.—The rail and section iron train has a three-high roughing-mill with rolls 30 inches in diameter and 6½ feet in length. The table is worked by hydraulic power, and power screwing gear is used. There is also a three-high finishing-mill with two stands and overhead hydraulic transferring gear. This mill has rolls 30 inches in diameter and 6½ feet long. It will roll girders with broad flanges up to 13¾ inches deep, steel sleepers, &c. It is driven by an engine of 1200 horse-power.

There is also a reversing-mill with three stands. The rolls are 24 inches in diameter and the table is 5¾ feet wide. It is driven by a double tandem compound reversing engine of 2500 horse-power. This train rolls rails of all sizes, and section iron up to 7·8 inches deep.

The hot ingots from the steel-works are reheated in three reheating furnaces with multitubular boilers. Adjacent to these mills are the conveying rollers, the hot shears, cooling floors, and a rail-finishing house, with machinery for straightening and drilling the rails. Farther on are the storage floors and loading-places.

Girder-Mill.—In a separate building is placed a mill with four stands of rolls 19·7 inches in diameter, and here are made tramway rails, girders, flats, fish-plates, &c. This mill has been used to re-roll old iron rails into girders, and since iron rails have been exhausted it is employed for rolling girders with straight flanges. This train is driven by a 600 horse-power engine, and it is served by two reheating furnaces with Belleville boilers.

Wire and Small Section Mill.—After the girder-mill is placed a group of three mills ranging from 13·4 to 9·84 inches in diameter for making wire. These works make a specialty of hard steel wire (20 to 21 gauge), with the high tensile strength of 50 to 57 tons per square inch. This mill also rolls small square sections for nails, rounds, flats, &c., and also strips for railway chair keys.

A shop containing punching, shearing, and drilling machines has been erected for dealing with the girders and fish-plates, and for cutting the strips for wedges.

Tire-Mill.—The manufacture of weldless tires was invented and commenced in 1856 at the St. Chamond Works. The methods adopted are peculiar to the works of this Company, and depend on the use of spherical ingots. These ingots are forged down to a cheese-like form under an 8-ton hammer, and are then forged in dies, and centrally perforated under a 15-ton hammer. The ring is reheated, and passed through two tire-mills, both with horizontal axles and hydraulic adjusting gear. Both mills are driven by an engine of 400 horse-power. There is also a hydraulic tire trueing machine and an annealing furnace.

Manufacture of David's Railway Chair Keys.—This manufacture is only carried on at the Adour Works. The David key is made from a thin steel strip, weighing 2·2 lbs., by bending it over upon itself so as to make an elastic key, which is used to replace wooden keys. This system of permanent way with rails held in chairs by the David key is used by the Midi, Western, Orleans, and State railways. The steel is rolled into strips, cut into lengths, and reheated prior to being shaped in hydraulic machinery. The wedge is then quenched, tempered, and tested for size and elasticity by driving it between a standard rail and chair. With three machines more than 10,000 wedges are turned out daily, and from 2,500,000 to 3,000,000 are made annually.

Additional Buildings.—A foundry and fitting shop have been erected to deal with the requirements of the works, and for making special articles for the tramways and railways.

The general arrangement of the plant at the Adour Works has been

designed with the object of utilising as much as possible the waste heat from the blast-furnace gas, from the coke ovens, and from the reheating furnaces. The engines are mostly compound, and condensing and sufficient power is thus obtained to satisfy all the requirements of the works. There are only five boilers fired with coal, and of these only three are at work. The consumption of steam-coal amounts to 198½ lbs. per ton of rolled products.

Consumption and Production of the Works.—

	Tons.
The consumption of ore	140,000 to 150,000
,, ,, limestone . . .	30,000 to 40,000
,, ,, English coal . .	110,000 to 120,000

The production of pig iron amounts to 75,000 to 80,000 tons, and of rails, sleepers, girders, wire wedges, section iron, tires, &c., is 45,000 to 50,000 tons.

Workmen.—Fifteen hundred men are employed at the works, for whom a town with schools, &c., has been built.

OBITUARY.

William Daniel Allen died at Endcliffe, Sheffield, on October 24, 1896, at the age of seventy-two years. Born at Chalfont, in Buckinghamshire, he was educated in London, and at the age of fifteen was apprenticed to Sir (then Mr.) Henry Bessemer, with whom he has ever since been intimately associated. In 1854 Mr. Allen went to America to supervise the erection of Bessemer's patent sugar-cane crushing and refining machinery. He also took an active part in the early experiments and subsequent development of the Bessemer steel process, and on the erection, in 1857, of the steel works at Sheffield he took over the entire management of the works, devoting himself laboriously and persistently to improve the quality and manufacture of steel. The first two years were mainly spent in further experiments, and the success of his management was signally complete, both from a scientific and a commercial standpoint. On the expiry of the partnership, after fourteen years' working, it was found that the firm had divided in profits fifty-seven times the capital embarked in the process, or 100 per cent. for every two months for twelve years; while the works, which had been largely extended out of revenue, were sold for twenty-four times the amount of the whole subscribed capital. In all, the partners received eighty-one times their original capital in fourteen years. This out of an invention which the Sheffield firms eyed askance. "I had immense difficulty," wrote the discoverer, "in persuading any one to touch it; indeed, neither the steel-makers nor the iron-makers would take it up after the lapse of two years," and from an establishment which started with a plant producing two or three tons per day, and employing a score of hands, now the Bessemer works produce over 2000 tons of steel per month, cover three acres of ground, and find work for a large number of people. Of course there are many larger establishments, even in Sheffield; for the intention of the founders was not so much to secure a large output, as to instruct those firms who wished to acquire the right to manufacture.

Mr. Allen, as the man on the spot, had to encounter many difficulties, but he never faltered in his faith in the ultimate success of his

efforts. He lived to see his hopes fully realised, and to witness, as he had predicted, that the Bessemer process must eventually revolutionise the steel world.

In using spiegeleisen for recarburising iron that has been wholly decarburised in the converter, much difficulty had been experienced in making a perfect mixture of these very different qualities of metal; and in order to remedy this defect, Mr. Bessemer invented and patented, on January 13, 1863, a mechanical agitator for thoroughly stirring the mixed metals while in the casting-ladle, and thus producing perfectly homogeneous ingots. Mr. Allen at once recognised the great advantage of this improvement, and has the credit of being the first, if not the only steel manufacturer to adopt it.

The agitator is an iron rod about 1½ inch in diameter; in one end is made a long aperture, through which is inserted the blade or plate of iron, twisted at each end. The ladle of steel, when it is turned out of the vessel, is brought beneath the agitator and raised by a hydraulic crane, immersing the blade and a portion of the rod in the steel. By means of rotatory motion, while the ladle is lowered and raised, the metal is thoroughly stirred. The stirring operation was found by Mr. Allen to be very simple in practice, causing no delay or inconvenience, and costing almost nothing; while the result in his own words, was that "Every ingot formed from the lowest charges was found by analysis to be perfectly uniform in temper and quality, while the thoroughly homogeneous quality of every part of the same ingot was evinced by its behaviour under the hammer or in the rolls, as well as in hardening and tempering." The same process is still largely in use to this day. Mr. Allen patented some valuable inventions for furnaces used in heating, and hydraulic machinery for manipulating steel.

In recognition of the great work he had done in bringing about the age of steel—which Sir Henry Bessemer had prophesied would supersede the age of iron, as iron had superseded the age of bronze—Mr. Allen was presented, in May 1890, with the Bessemer Gold Medal of the Iron and Steel Institute. The specific work for which this distinction was bestowed on him was his early successful service in manufacturing a high quality of Bessemer steel.

When the original partnership expired in 1877, Mr. Allen took over the whole business, and converted it into a private limited liability company, consisting of himself and his family. In 1889 a number of shares were made available for the public. Mr. Allen, who was a

director of the Carlton Main Colliery, took no part in political or other public affairs.

He was elected a member of the Iron and Steel Institute in 1872, and contributed papers to the Proceedings, in 1881 on the use of a mechanical agitator in the manufacture of Bessemer steel, in 1883 on Bessemer steel in its cast and unwrought state, and in 1891 on the forging press.

William Brockbank died on September 18, 1896, in the sixty-seventh year of his age. Eldest son of Mr. W. Brockbank, who executed numerous important engineering works in the Manchester district, he served his apprenticeship with Mr. Thomas Carrick, then a well-known surveyor, with whom, in 1853, he entered into partnership. The firm of Carrick & Brockbank, of which he was senior partner at the date of his death, had a large practice in surveying for railways and water-works. Mr. Brockbank was a justice of the peace for Cumberland, Fellow of the Geological Society, and was elected a member of the Iron and Steel Institute in 1872.

James Lyons Cleminson died at his residence, 35 Chester Terrace, Regent's Park, on November 15, 1896, at the age of fifty-six. He was the eldest son of the late Mr. John Cleminson, who was locomotive superintendent of the Iquique, or the original Nitrate Railway, and who was also a naval engineer, and had fought in the Baltic and under Garibaldi. His son was educated at Genoa and Marseilles, and at an early age gave indication of that engineering skill for which he was subsequently noted. He served his apprenticeship under Mr. John England, of Hatcham Iron-works, and was then employed as chief draughtsman to the Somerset and Dorset Railway, where his aptitude in designing rolling-stock was speedily recognised. He afterwards came to London, and was appointed manager to Mr. Robert Fairlie, with whom he was intimately associated in designing and bringing out the Fairlie locomotive. For several years he was chief of the drawing department, and technical adviser to the Isca Foundry Company, Newport, and on returning to the metropolis he occupied several important positions in connection with the firm of Clarke, Punchard & Co. In 1874 he commenced business as a civil and consulting engineer; and amongst the many projects with which he has been identified as consulting engineer are the Buenos Ayres and Pacific Railway, of which he was the originator, Bahia Blanca and North-Western, Ville Maria and Rufino, Bahia and San Francisco,

and North Wales Narrow-Gauge Railway. He was also consulting engineer to the only railway in China, viz., the Imperial Railway of North China. In this capacity he frequently came into contact with Li Hung Chang, and was created a Chinese mandarin in recognition of his distinguished services. Having spent a considerable time in China, Mr. Cleminson possessed an intimate knowledge of that empire and its resources. He had also bestowed upon him various decorations from different parts of the world in appreciation of his railway enterprise. He was the inventor of the Cleminson composite wheel, and of the well-known flexible wheel base, the utility of which was universally recognised. Besides possessing a rare engineering knowledge, he devoted himself especially to the study of the chemical composition of steel. Mr. Cleminson was a member of the Institution of Civil Engineers, a member of the Institution of Mechanical Engineers, and a Fellow of the Royal Geographical Society. He was elected a member of the Iron and Steel Institute in 1882.

William George Dowden died at his residence, Park House, Blaenavon, Monmouthshire, on November 19, 1896, at the age of forty-seven. He was manager of the Blaenavon Works, and had held that position for four and a half years, having succeeded the late Mr. John Worton. He was elected a member of the Iron and Steel Institute in 1894.

Matthew Gray died at his residence, The Willows, West Hartlepool, on June 16, 1896, aged forty. The eldest son of Sir William Gray, he was born at Hartlepool in 1856, and received his education at Rodridge House School, and afterwards at Harrogate College, finally completing his studies at Hanover. On his return, at the age of seventeen, he entered his father's office, and a few years later was taken into partnership as a member of the firm of William Gray & Co., which in 1889 was incorporated as a private limited liability company. In 1881 he acquired the West Hartlepool Rolling Mills, and subsequently laid down steel-making plant, which has been in operation for eight years. In addition to being interested in the works mentioned, he was a partner in the Hartlepools' Salt and Brine Co., and was also connected with the British Expanded Metal Works. He was elected a member of the Iron and Steel Institute in 1891.

James Henry Greathead died at his residence, Streatham, on October 21, 1896. He was a member of the Council of the Institution of Civil

Engineers, and had carried out many extensive engineering works; but he will be chiefly remembered as the pioneer in that system of tunnelling which bears his name, has revolutionised the method of tunnelling hitherto adopted in large cities, and has practically solved the problem of rapid transit in London. The City and South London Railway, which was one of the first to be constructed by Mr. Greathead, has been in operation about five years. The Central London and the Waterloo and City Railways are in course of construction, and others are authorised. These tunnels would not have been practicable had it not been for the very ingenious device known as the Greathead shield, which enables tunnels to be driven with safety and economy underneath buildings of all kinds without disturbance, and under rivers without danger to the workmen. This shield, together with the Greathead grouting machine, will always be associated with his name. These appliances have been used in Glasgow, Edinburgh, Liverpool, and elsewhere in the British Isles, as well as in Canada, Australia, and other parts of the world. Mr. Greathead was elected a member of the Iron and Steel Institute in 1892, in which year he contributed to the Proceedings of the Institute an important paper on the Liverpool Overhead Railway.

Howard John Kennard died at the Orleans Club, Brighton, on August 8, 1896, in his sixty-seventh year. His kind nature, geniality of disposition, and largeness of heart, evoked from all who knew him feelings of affectionate regard. He was the son of the late Mr. R. W. Kennard, M.P. His connection with the iron trades extended over a long period of years. He was the chairman of the Blaenavon Iron Company, and senior partner in the Falkirk Iron Company. His other connections in commercial and public life were numerous. He was a justice of the peace for Stirlingshire, the deputy-chairman of the Northern and Eastern Railway, and a director of the Great Eastern Railway. In the city of London he was distinguished as one of her Majesty's lieutenants for the city, and also as a Past-Master of the Carpenter's Company. Perhaps, however, it was as President of the Royal Iron, Hardware, and Metal Trades' Pension Society that he was most widely and popularly known. It was in the year 1891, upon the retirement of Colonel Robert Stedall, that Mr. Kennard, by the unanimous vote of the subscribers, was elected president of the trade's only charitable institution, and of which his father was the founder. His connection with that charity commenced in early boyhood, for at the age of fifteen he contributed his first donation. In the half-century that has since elapsed, he has always shown himself to be a firm and

most generous advocate of its interests. Among the many business undertakings in which Mr. Howard Kennard was interested was the London Stereoscopic Company, which he helped to establish. He was an Associate of the Institution of Civil Engineers, and was elected a member of the Iron and Steel Institute in 1884.

GEORGE LITTLE, a director of Messrs. Platt Brothers (Limited), Oldham, died on July 30, 1896, at the age of seventy-three. A native of Leeds, he had been connected with Messrs. Platt Brothers for fifty-two years as workman, foreman, manager, and director. He was very successful in devising labour-saving appliances, for which he held many patents. He took special interest in the Werneth Mechanics' Institute, and was a warm advocate of technical education. He was a member of the Institution of Mechanical Engineers, and was elected a member of the Iron and Steel Institute in 1881.

Sir JAMES RAMSDEN died October 19, 1896, at the age of seventy-four, after a lingering illness, at Abbots Wood, his residence at Furness Abbey. To him more than to any other man the prosperous north Lancashire town of Barrow-in-Furness owes its remarkable growth. Although deposits of hæmatite iron ore had for more than a century previously been known to abound in the Furness peninsula, lying between Morecambe Bay and the estuary of the Duddon, it was not until the year 1840 that any serious and systematic effort was made to utilise those extensive deposits. Mr. Schneider's discovery of the hidden wealth of the ironfield led to the construction of the Furness Railway, and there is no name more prominently associated with that enterprise than the name of Sir James Ramsden. He was the company's first engineer. He became general manager and secretary of the line, and twenty years ago was appointed its managing director, as he had long before been its chief controlling spirit. The Duke of Devonshire and the Duke of Buccleuch, as the two principal landowners, helped on the rapid development of the town by constructing capacious docks, affording accommodation for the vessels of considerable draught which have since been engaged in continually expanding the trade of the port, until from an insignificant fishing village it has assumed the importance of a thriving and well-ordered industrial centre numbering 60,000 inhabitants. It was not, however, merely in the Furness Railway that the indomitable energy of Sir James Ramsden was witnessed. He played an active part in bringing about the union which led to the creation of the well-known Barrow Hæmatite Steel Company

(Limited), of which he was a director; and similarly he interested himself in bringing into being the company which introduced shipbuilding on a large scale to Barrow. The town showed its warm appreciation of his work by electing him as its first mayor after incorporation, by inviting him to retain that office in four successive years, and by erecting in the very centre of the town during his life a massive bronze statue recording the high appreciation in which his services were held by the entire community. His devotion to the public interest, manifested as it was by acts of private beneficence as well as by bold municipal ambition, further earned for him the honour of knighthood, which was conferred by her Majesty in 1872. He was a deputy-lieutenant and a justice of the peace for Lancashire, of which county he was also high sheriff in 1873; a magistrate in the adjoining county of Cumberland, honorary colonel of the 1st King's Own Lancaster Volunteers, having received the volunteer officers' decoration; and up to the time of his illness he continued, notwithstanding his advanced age, to take an active part in all that concerned the welfare of the borough.

Sir James Ramsden was a member of the Institution of Civil Engineers, and a Vice-President of the Institution of Mechanical Engineers. He was one of the original members of the Iron and Steel Institute, and was elected a Member of Council in 1871, and a Vice-President in 1881.

WILLIAM SHAW died on June 29, 1896, at the age of seventy years. He was one of the pioneers of the introduction of steel castings, and established a considerable business in them. He was for many years manager of Attwood's Steel-works, Wolsingham, where he practically worked out the Attwood process of steel-making. Some ten years ago he became connected with the Cast Steel Foundry at Middlesbrough, and shortly afterwards started the Wellington Cast Steel Foundry there, which he worked very successfully, executing considerable orders in his speciality for the Admiralty. He was a member of the Institution of Mechanical Engineers, and was elected a member of the Iron and Steel Institute in 1872.

JAMES TAIT died at his residence, Garmond-Sway, near Coxhoe, on June 11, 1896, aged fifty-three. He was manager of Raisby Hill Limestone Quarries, a position he had held for upwards of twenty years. He was elected a member of the Iron and Steel Institute in 1879.

ADDITIONS TO THE LIBRARY

DURING THE SECOND HALF OF 1896.

Title.	By whom Presented.
"Summaries of Statistics relating to Mines and Quarries." London. 1896.	Professor C. Le Neve Foster.
"The Commercial Federation of the British Empire." By J. S. Jeans. London. 1896. (Pamphlet.)	The Author.
"List of Mines in the United Kingdom." London. 1896.	Professor C. Le Neve Foster.
"Mineral Products of the United States." Washington. 1896.	The United States Geological Survey.
"List of the Plans of Abandoned Mines Deposited in the Home Office."	Professor C. Le Neve Foster.
"Illustrated Official Guide to Cardiff Exhibition." Cardiff. 1896.	Mr. E. P. Martin.
"Official Catalogue of the Cardiff Exhibition."	Mr. E. P. Martin.
"Illustrated Handbook of Cardiff Exhibition."	Mr. E. P. Martin.
"Smoke Prevention and Fuel Gas." By J. D. Weeks. Cincinnati. 1896.	The Author.
"Proceedings of the Australasian Association for Advancement of Science." Vol. vi. Sydney. 1896.	The Association.
"The Engine Boiler and Employers' Liability Insurance Company, Limited, Chief Engineer's Report for 1895." Manchester. 1896.	The Company.
"The Detection and Measurement of Inflammable Gas." By F. Clowes and B. Redwood. London. 1896.	Messrs. Crosby Lockwood & Son.
"Methods of Mine Timbering." By W. H. Storm. 2nd edition. Sacramento. 1896.	Mr. W. J. Sharwood.
"Die Anwendung des Thermopyrometers." By H. Wedding. 1896. (Pamphlet.)	The Author.
"Herstellung und Verwendung von Flusswaaren." By H. Wedding. Berlin. 1896. (Pamphlet.)	The Author.

Title.	By whom Presented.
"Die Reise des Britischen Iron and Steel Institute nach Spanien." By H. Wedding. Berlin. 1896. (Pamphlet.)	The Author.
"The Structure of Metals: Its Origin and Changes." By W. C. Roberts-Austen.	The Author.
"Bakerian Lecture on the Diffusion of Metals." By W. C. Roberts-Austen. London.	The Author.
"Bulletin of the Department of Labour." Washington. 1896.	Mr. Carroll D. Wright.
"Sur l'Emploi du Peroxyde de Sodium." By H. A. Brustlein. Saint-Etienne. 1896.	The Author.
"Railway Rates and Terminal Charges." By R. Price-Williams. London. 1896. (Pamphlet.)	The Author.
"Ironmonger's Hall." London. 1896. (Pamphlet.)	Mr. R. C. Adams-Beck.
"Mineral Statistics of the United Kingdom for the Year 1895." London. 1896.	Professor C. Le Neve Foster.
"Chemical Analysis of Iron." By A. A. Blair. 3rd edition. Philadelphia. 1896.	The Author.
"Compendium des Eisenhüttenkunde." By the Baron H. von Jüptner.	The Author.
"Biographical Sketch of Sir Henry Bessemer." By R. H. Thurston. New York. 1896. (Pamphlet.)	Sir H. Bessemer.
"The Manufacture and Properties of Structural Steel." By H. H. Campbell. New York. 1896.	The Author.
"The Production of Iron Ore in 1895." By John Birkinbine. Washington. 1896. (Pamphlet.)	The Author.
"Iron Making in Alabama." By W. D. Phillips. Alabama. 1896.	The Author.
"The Elective System in Technological Schools." By M. E. Wadsworth. Michigan. 1896. (Pamphlet.)	The Author.
"Eiserne Flaschen zur Aufbewahrung von Gasen." By A. Martens. Berlin. 1896. (Pamphlet.)	The Author.
"Syllabus of the Course of Mining Engineering and Metallurgy at the Massachusetts Institute of Technology." Boston. 1896.	The Institute.
"Swedish Mineral Statistics for 1895." Stockholm. 1896.	R. Åkerman.

Title.	By whom Presented.
"Second Annual General Report upon the Mineral Industries of the United Kingdom." By C. Le Neve Foster. London. 1896.	The Under Secretary of State.
"Historical and Technical Account of the Origin of the Bessemer Process." By Sir Henry Bessemer. New York. 1896. (Pamphlet.)	The Author.
"Berg- und Hüttenmännische Zeitung." Leipzig. 27 vols. 1862 to 1888.	Mr. John Darlington.
"Hunt's Mineral Statistics." 1848 to 1880.	Mr. John Darlington.
"Traité de la Fonte." By Flachat, Barrault and Petiet. With Folio Atlas. 1851.	Mr. John Darlington.
"Iron Metallurgy." By S. B. Rogers. London. 1857.	Mr. John Darlington.
"Karmarsch's Technical Dictionary." Vol. i.	Mr. John Darlington.
"Report of the Juries." London. 1851.	Mr. John Darlington.
"Mining at Great Depths." By Bennett H. Brough. London. 1896. (Pamphlet.)	The Author.
"Kohlentstoff-formen im Eisen." By Baron H. von Jüptner. Stuttgart.	The Author.

INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions :—

LONDON.

Board of Trade.
Chemical Society.
City and Guilds Institute.
Geological Society.
H.M. Patent Office.
Imperial Institute.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Institution of Naval Architects.
Royal Artillery Institution.
Royal Institute of British Architects.
Royal Institution.
Royal Society.
Royal Statistical Society.
Royal United Service Institution.

Society of Arts.
Society of Chemical Industry.
Society of Engineers.
University College.

PROVINCIAL.

Cleveland Institution of Engineers.
Hull and District Institution of Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Liverpool Engineering Society.
Liverpool Polytechnic Society.
Manchester Association of Engineers.
Manchester Geological Society.
Mason Science College (Birmingham).
Merchant Venturer's School (Bristol).
Mining Institute of Scotland.
North-East Coast Institution of Engineers.
North of England Institute of Mining and Mechanical Engineers.
Sheffield Technical School.
South Staffordshire Institute of Iron and Steel Works Managers.
South Staffordshire Ironmasters' Association.
South Wales Institute of Engineers.
University College of South Wales.

COLONIAL AND FOREIGN.

Colonial.

Canadian Institute.
Canadian Society of Civil Engineers.
Department of Mines, Sydney.
Department of Mines, Melbourne.
Geological Survey of Canada.
Geological Survey of India.
Mining Society of Nova Scotia.
Royal Society of New South Wales.

United States.

American Association for the Advancement of Science.
American Institute of Mining Engineers.
American Iron and Steel Association.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Bureau of Statistics.
Engineers' Society of Western Pennsylvania.
Franklin Institute.
Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institute.
United States Geological Survey.

Austria.

K.k. geologisches Reichsanstalt.
Oesterr. Ingenieur und Architekten-Verein.

Belgium.

Ministère de l'Interieur.

France.

Comité des Forges.
Le Ministère des Travaux Publics.
"Revue Maritime." Ministère de la Marine.
Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Anciens Eleves des Écoles Nationales d'Arts et Métiers.
Société des Ingénieurs Civils.
Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreningen.

Germany.

Königliche Bergakademie in Freiberg.
Königliche Technische Versuchsanstalt.
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eisen.")
Verein Deutscher Ingenieure.

Italy.

Reale Accademia dei Lincei.

Japan.

Department of Mines.

Sweden.

Jernkontoret.

JOURNALS.

The following periodicals have been presented by their respective Editors:—

UNITED KINGDOM.

"Bimetallist."
"British Trade Journal."
"Coal and Iron."
"Commerce."
"Contract Journal."
"Colliery Guardian."
"Daily Tenders and Contracts."

"Electrician."
"Electrical Plant."
"Electrical Engineer."
"Engineer."
"Engineer and Iron Trades Advertiser."
"Engineering."
"Engineering Review."
"Engineers' Gazette."
"Hardwareman."
"Hardware Trade Journal."
"Industries and Iron."
"Invention."
"Iron and Steel Trades Journal."
"Iron and Coal Trades Review."
"Ironmonger."
"Ironmongery."
"Iron Trade Circular."
"Marine Engineer."
"Machinery Market."
"Phillips' Monthly Register."
"Plumber and Decorator."
"Practical Engineer."
"Railway Engineer."
"Railway World."
"Science and Art of Mining."
"Shipping World."
"Statist."
"Steamship."
"The London Technical Education Gazette."
"Tool and Machinery Register."
"Transport."

COLONIAL AND FOREIGN.

Colonial.

"Canadian Mining Review."
"Indian and Eastern Engineer."
"Indian Engineering."

United States.

"Age of Steel."
"American Journal of Science."
"American Manufacturer."
"Bradstreet's."
"Cassier's Magazine."
"Colliery Engineer."
"Digest of Physical Tests."
"Engineering and Mining Journal."
"Engineering Magazine."

"Engineering News."
"Iron Age."
"Iron Trade Review."
"Railroad Gazette."
"Report of Proceedings of the Master Car Builders' Association."
"Stowell's Petroleum Reporter."

Austria.

"Oesterr. Zeitschrift für Berg- und Hüttenwesen."

Belgium.

"Association des Ingénieurs de Liége."
"Association des Maîtres des Forges de Charleroi."
"Bulletin de l'Union des Charbonnages de Liége."
"Moniteur des Intérêts Matériels."
"Revue Universelle des Mines."

France.

"Annales des Mines."
"L'Echo des Mines."
"Le Génie Civil."
"Portefeuille Économique."

Germany.

"Annalen für Gewerbe und Bauwesen."
"Baumaterialienkunde."
"Chemiker Zeitung."
"Glückauf."
"Verein Deutscher Eisen und Stahl Industrieller."
"Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."
"Zeitschrift für praktische Geologie."

Italy.

"L'Industria."
"Rassegna Mineraria."

Spain.

"Revista Minera."

Sweden.

"Teknisk Tidskrift."

SECTION II.

NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

CONTENTS.

ABSTRACTORS.

EDWIN J. BALL, Ph.D.

BENNETT H. BROUGH, Assoc. R.S.M.

IRON ORES.

CONTENTS.

I.—*OCCURRENCE AND COMPOSITION.*

The Occurrence of Gallium in the Cleveland Iron Ore.—In the course of an investigation of flame spectra at high temperatures, W. N. Hartley and Hugh Ramage* have examined the flames from the converters of the basic Bessemer process at Middlesbrough-on-Tees. A large number of photographs were taken, which are stated to have been remarkably fine in definition, and extending from the less refrangible limit of the red rays to the ultra-violet above wave-length 3240. The authors have identified all the lines and bands represented, and by this means have proved the presence of the rare element *gallium* in the Bessemer metal, and in the roasted ore from which it was extracted. Careful analyses showed that the gallium was concentrated in the iron. The lines 4171·6 and 4032·7 (on Rowland's scale) were repeatedly observed in the spectrum of the Bessemer flame, again in that of the mixer metal, and of the residue or precipitates separated from it, and finally in that of the residues obtained upon treatment of the roasted Cleveland ore itself.

Canadian Iron Ores.—G. C. Hoffmann † has published the results of analyses of iron ores from various localities in Canada. The

* *Proceedings of the Royal Society*, vol. lx. pp. 35–37.

† *Geological Survey of Canada. Annual Report*, vol. vii., pp. 16–20R.

specimens examined include magnetite from North Mountains, Annapolis Co., Nova Scotia; hæmatite from the same locality, and from Cow Bay, Cape Breton Co., Nova Scotia; limonite from Kilkenny, Montcalm Co., Quebec; magnetite from Rawdon, Montcalm Co., and from Wexford, Terrebone Co., Quebec; hæmatite with magnetite, magnetite with hæmatite, and magnetite alone, from Koksoal River, Labrador Peninsula; ankerite with magnetite, and magnetite from the same place; magnetite from between Petitsikapou and Dyke Lakes, Labrador Peninsula; magnetite with hæmatite from Menihek Lake, Labrador Peninsula; magnetite from Minden, Haliburton Co., Ontario; from Digby, Victoria Co., Ontario; from Lutterworth, Haliburton Co., Ontario; from Galway, Peterborough Co., Ontario; and from Snowdon, Peterborough Co., Ontario.

R. Chambers mentions deposits of bog iron ore at Maugerville, Sunbury Co., N.B., on the banks of the North-west Miramichi River above Chaplin Island, on the south side of Buctouche Harbour, in Kent Co., New Brunswick, to the south of the Richibucto River, and on the south side of the Kouchibougac River. He also mentions a bed of magnetite discovered a few years ago near the head of the Millstream, Gloucester Co. Analyses gave 60 per cent. of metallic iron and 10 per cent. of silica. The development of this bed was abandoned four or five years ago.

During the year 1893, according to E. D. Ingall, the production of iron ore was as follows:—

	Tons.
Nova Scotia	102,201
Quebec	22,076
British Columbia	1,325
	125,602

G. M. Dawson notes the occurrence of considerable quantities of magnetic iron ore in the rocks near Kamloops Lake. On analysis the ore gave 66·83 per cent. of metallic iron, and very little phosphorus or sulphur. From 1889–94 the principal deposits have been worked intermittently, and 4700 tons of ore produced.

R. W. Ellis mentions the places in Quebec in which iron ore occurs. The ore in these localities is sometimes magnetic, sometimes specular, and at times contains as much as 28 per cent. of titanic acid. At Potton occurs a deposit of iron pyrites overlain by bog-iron ore from 1 to 3 feet thick. At Potton has also been found chromic ore, sufficiently rich in chromic oxide for shipment, and it is expected that workable deposits will one day be found in this neighbourhood.

R. W. Ellis gives the analysis of iron ore mined from October 1891 to March 1892 near St. Jerome, County of Terrebone, during which period 365 tons of ore were extracted and smelted. He also gives the analysis of a highly titaniferous ore found at St. Julienne, Rawdon; and mentions the finding of iron ore near Wexford.

R. Chambers mentions an extensive deposit of bog-manganese near Dawson Settlement, Albert County, New Brunswick.

Iron Ore in Ontario.—A. P. Coleman * briefly reviews the mining industry in Ontario, and amongst the minerals obtained, iron ore is mentioned. Deposits of all the chief ores are found. The Upper Laurentian of the Ottawa valley contains, especially near outcrops of crystalline limestone, many ore bodies, some of considerable dimensions, most of them magnetite, but some hæmatite. Southern Ontario has more or less extensive areas of bog iron ore, and Western Ontario has immense beds of magnetite ore in the Atikokan and Greenwater Lake regions, and still greater beds of hæmatite along the Mattawin River; whilst low-grade siderite has been found to the east of Port Arthur. Smelting on a very small scale was carried on before 1845, but since then none has been done, and it will be of interest to see how the experiment of smelting these ores at Hamilton with American coke will answer. Before 1891 Ontario appears to have exported about 600,000 tons, but owing to the competition of the Lake Superior mines, nothing has been done in the last few years.

Iron Ore in Nova Scotia.—E. Gilpin † states that a collection of the minerals of Nova Scotia is being prepared for the Imperial Institute. A prominent place is taken by the iron ores, of which there are seventy-five specimens of different varieties. Coal, iron, and steel are represented, and some twelve samples of rich manganese ores from Hants County and elsewhere also find a place in the collection.

E. Gilpin ‡ gives some notes on the iron ores of Nictaux, in Annapolis County, Nova Scotia, in view of their usefulness for steel manufacture. The Nictaux district is about thirty miles to the south of Annapolis, and contains rocks referred to the Devonian age. The iron ore-bearing country is about five miles broad in parts, and the ore is shown in frequent exposures which run in a north-easterly direction. The most

* *Journal of the Canadian Mining Institute*, vol. i. pp. 1–11.

† *Ibid.*, vol. i. pp. 193–195.

‡ *Proceedings of the Nova Scotia Institute of Science*, vol. ix. pp. 10–20.

northerly range is worked in the Torbrook mine. South of this is the fossiliferous "shell" ore, 5 to 8 feet in thickness, and still farther south are two beds of red hæmatite, 4 to 6 feet thick. Other beds of magnetite are also exposed, some of which reach a thickness of 20 feet, and have been traced for six miles. The magnetites contain 0·5 to 2·0 per cent. of phosphorus. As a rule, they are siliceous, and in some cases manganiferous, but are low in sulphur, and so, except for the silica, would answer for the basic process. A large number of analyses are given of both magnetites and hæmatites. At Torbrook the ores range from—

Iron.	Silica.	Phosphorus.	Sulphur.	Lime.	Alumina.
47 to 60	6 to 17	none to 1·66	none to 0·23	up to 2·7	up to 5·53.

Several attempts were made, dating back to 1829, to use these ores. From one mine about 80,000 tons have been raised.

The Iron Ores of Upper Silesia.—In a paper read before the Verein deutscher Eisenhüttenleute, F. G. Bremme * states that the brown iron ores occurring in the muschelkalk formation in Upper Silesia are probably products of the oxidation of pyrites and the decomposition of ferruginous dolomite. These form now almost the sole remaining ore supplies of the district, as the clay ironstones of the Carboniferous beds are almost completely worked out, and this also refers to the Jurassic ores. The brown iron ores of the muschelkalk are found throughout the whole of this, from its southern limits up to the north of Georgenberg, and westwards as far as Wieschowa. They occur in irregular pockets or beds, and are worked by open workings or shallow shafts to a depth of 130 feet; the iron ore mining is often a subsequent exploitation after mining for zinc ores or ores of lead. The total output of these brown iron ores in Upper Silesia in 1895 amounted to about 470,000 tons.

In character these ores are usually soft, and when dried will contain from 35 to 40 per cent. of iron; or, as mined, from 20 to 30 per cent. of iron, and from 25 to 35 of water. Sometimes the percentage of iron in the dry ore reaches 50, or even more. Zinc occurs in quantities of 2 or 3 per cent. or more, and renders the blast-furnace practice difficult. On the other hand, the ores contain some highly argentiferous galena, and the lead obtained in the blast-furnace treatment is a welcome by-product. So much so, indeed, that all blast-furnaces of Upper Silesia in which much of this brown iron ore is smelted are specially arranged for the

* *Stahl und Eisen*, vol. xvi. pp. 755–764.

collection of the lead. The manganese contained in these ores is very variable in quantity, varying from but a fraction of 1 per cent. to more than 5. The percentage of sulphur contained in the ore is very low; and the pig iron obtained from the ores is not red-short, and yields an excellent puddle-bar.. The percentage of phosphorus varies from 0·02 to 0·2 per cent.

Iron Ore from Algeria.—M. Simon * has analysed various specimens of Algerian iron ore. In a brown hæmatite from Rivet he found 44·8 per cent. of iron, and 2·6 per cent. of manganese. Three specimens of iron ore from Oran contained respectively 68·7, 68·4, and 66·0 per cent. of iron, whilst a red hæmatite from Charon gave the following results:—

SiO_2.	Al_2O_3.	Fe_2O_3.	CaO and MgO.
20·7	7·40	54·60	17·30

Iron Ore of the United States.—The iron ores of Lake Superior continue to be the main source from which nearly all the furnaces north of the Ohio and west of the Alleghenies draw their supplies.

The fifteenth annual report of the United States Geological Survey has been issued by the Government printer. A handsome volume of 755 pages with forty-eight plates, it contains the usual administrative reports and some valuable special papers, including a preliminary report on the remarkable mining district visited by the Iron and Steel Institute in 1890, the Marquette iron-bearing district of Michigan, by Professor C. R. Van Hise, Mr. W. S. Bayley, and Mr. H. L. Smyth.

In the Southern United States, W. M. Brewer † reports that last year the output of iron ore from the Red Mountain district, Alabama, was the largest in the history of the State. The persistency of the larger and more important deposits of limonite in Alabama and Georgia is in many cases surprising to the owners themselves. The red ore district of Georgia was especially active last year.

A. Lakes ‡ describes the important deposits of manganese on the Cebolla River, describing their geology, topography, and development.

J. F. Fuller § describes the iron resources of the State of Texas.

* *Annales des Mines*, vol. ix. p. 563.
† *The Mineral Industry*, New York, vol. iv. p. 391.
‡ *Colliery Engineer*, vol. xvi. pp. 267–268.
§ *Tradesman*, July 1, 1896.

Hæmatite from Elba.—In the following analyses, by R. Rohrer,* the mineral was reduced by hydrogen—

Fe_2O_3.	SiO_2.	CaO.	MgO.	Total.
98·58	0·51	0·38	0·73	100·20
98·63	0·47	0·45	0·74	100·29

Manganese and ferrous iron are absent, and there is no loss on ignition. In another paper E. A. Wulfing † gives the refractive indices and the specific gravity (5·285) for the same material.

Artificial Specular Iron Ore.—J. Knett ‡ notes the formation of iron glance on the burnt surface of salted clay wares, and he concludes that this is brought about by the following reactions. The clay ware, $(AlFe)_2O_3 + x\ SiO_2$ yields with salt the silicate of alumina and sodium, which forms the glaze desired, and ferric chloride. The latter is then converted by the water vapour present into ferric oxide and hydrochloric acid, according to the reaction—$Fe_2Cl_6 + 3H_2O = Fe_2O_3 + 6HCl$.

Basic Sulphate of Iron from Mount Morgan, Queensland.—According to T. Cooksey, § this mineral occurs as dull, compact, brown nodules in a matrix of iron oxide; the powder is yellow and crystalline. No water is given off below 175°. Analysis gave—

Fe_2O_3.	Na_2O.	K_2O.	SO_3.	H_2O.	Total.
49·13	4·43	3·88	33·31	9·96	100·71

The substance differs from jarosite in the proportion of potassium and sodium, and in being almost insoluble in water.

Meteoric Iron.—O. Vogel ‖ observes that a century has elapsed since Chladni published his investigations relating to the meteoric iron discovered at Krasnojarsk. It was a bold achievement in those days to propound the theory of their non-terrestrial origin. Meteoric iron contains a large number of foreign elements. Nickel is always present, and this is usually accompanied by cobalt; copper, chromium, carbon, sulphur, and phosphorus also occur in it. Manganese and tin have been stated to have been observed in several instances, but the presence of these elements, as also of arsenic, antimony, and zinc, is more doubtful. Most

* *Tschermaks Mineralogische Mittheilungen*, vol. xv. pp. 184-187.
† *Ibid.*, p. 68.
‡ *Thonindustrie Zeitung*, vol. xx. p. 495.
§ *Records of the Australian Museum*, vol. ii. pp. 111-112.
‖ *Stahl und Eisen*, vol. xvi. pp. 442-448, 491-496, and 536-540.

meteorites, too, contain gases, and especially nitrogen, hydrogen, carbon monoxide, and carbon dioxide. Dealing with the various constituents in detail, the author first considers nickel. It may, he observes, be safely stated that this element has been found in every meteorite examined, though in varying percentages. A larger percentage than 11 is rare, but still the percentage varies from about 6 up to 20. Native terrestrial iron also usually contains nickel, but either in much smaller percentages—0·25 to 4 in the case of Greenland iron—or in much higher percentages, as in the case of the New Zealand discovery, which contained 68 per cent. of nickel. The author tabulates 19 meteorites, showing their physical properties, and the percentages of nickel and cobalt they contain. The nickel varies from 0·071 (including cobalt) to 62·01 per cent., but 18 of the 19 contained under 17 per cent., and 16 had not more than 10 per cent. In only one case does the cobalt exceed 1 per cent.—2·037 being the percentage noted. Most of the meteorites were malleable, and some very much so, but one or two were brittle. Their fracture differed, some being granular, some crystalline, and in some no definite structure was noted. One is stated not to rust in damp air. In only one case is the specific gravity given—7·816. This is given for the Bendego meteorite which fell in 1784, and contained from 3·9 to 5·1 per cent. of nickel. As the percentage of nickel increases, the colour of the alloy grows lighter. The specific gravity varies considerably, being usually between 7·6 and 7·9; the specific gravities of pure iron and of pure nickel being respectively 7·88 and 8·8. Some meteorites, such as the Toluca fall, may be welded, but cannot be hardened. The author thinks that the numerous differences noted in the physical properties of the different meteorites are readily understood when it is remembered that these do not consist of pure iron and nickel, but contain sulphur, phosphorus, and other impurities, as in pig iron. The author instances seven meteorites which, while containing from 4·01 to 24·708 per cent. of nickel, contained also from 0·79 to 4·00 per cent. of sulphur, and three in which the phosphorus varied from 0·78 to 1·229 per cent. With regard to their magnetic properties, much that has been written about this is not in accord. Some behave like steel, and others like soft iron, the abnormal behaviour of the latter being possibly due to their having been strongly heated.

With regard to solubility, meteoric iron is more or less soluble in acids, according to whether its percentage of nickel is low or high. It is also soluble in copper sulphate solution and other solvents. According to their behaviour with copper sulphate solution, they may be

divided into the two classes "passive" and "active." The former do not reduce it, while the latter do. Some occupy an intermediary position, decomposing the sulphate after some time. Those meteorites which are relatively low in nickel rust readily, but those which contain much of this element do so to a much less extent.

With regard to the presence of cobalt in meteorites, this element is nearly always present, in quantities varying from 0·5 to 2·5 per cent., the meteorites very rich in nickel being often relatively rich in cobalt. Billings has found that an ingot iron containing 0·33 per cent. of cobalt was very soft and tough in the cold, though it was somewhat red-short. Cobalt vapour is absorbed by iron, but given out again *in vacuo*. This behaviour is the opposite to that of nickel, which will even absorb iron vapour.

A third element, which is always present, even though occasionally only in traces, is copper. Its percentage varies usually between 0·006 and 0·026 per cent. Chromium is also found, sometimes in daubrielite, FeS,Cr_2S_3, but more usually as chromite. This latter usually occurs only in very small quantities, 0·01 to 0·03 per cent. Chromite is by no means a rare constituent in meteorites, still its percentage is, as stated, usually very small.

Other metals have also been met with, as has already been pointed out. Of the non-metallic constituents, carbon, sulphur, phosphorus, and the occluded gases; with regard to carbon, the percentage of graphite found in meteorites is very variable. As a rule, it occurs in the form of nodules, reaching at times a hundred grammes in weight. At times, too, it is found in the form of sheets, up to 10 centimetres in length and 5 in width. The total percentage appears to vary from 0·03 to 1·170. It is possible that graphite may not be a primary constituent of the meteoric iron, but may result by separation after heating.

The diamond has been found in meteorites. Graphitic temper carbon appears also to occur, Cohen having found from 0·007 per cent. to 0·0935 per cent. of "amorphous" carbon, with which this temper carbon appears to accord. Hardening carbon seems to occur in quantities of from 0·02 to 0·164 per cent., and carbide carbon is also present. The carbide $(FeNiCo)_3C$ has been observed in the Magara meteorite, and similar carbides have also been noted in others. The hardness varies from 5½ to 6, and the specific gravity from 7·227 to 7·244. Both chemically combined carbon and carbon in mechanical admixture occur, therefore, in meteoric iron, and Beck's statement that this is not the case, in his "History of Iron," is therefore inaccurate.

Phosphorus was noted in 1832 by Berzelius as being present in the form of an iron nickel phosphide, which was subsequently named Schreibersite. Rhabdite is identical with this in chemical composition, this being $(FeNiCo)_3P$, and agrees, therefore, with the phosphide Fe_3P, which occurs in manufactured iron. The presence of the phosphide Fe_2P has also been thought to have been observed. Iron-nickel phosphide is so common a constituent of meteoric iron that some authors have considered it the salient feature in meteorites. In percentage it usually varies between 1·73 and 8·11.

Sulphur exists in meteoric iron in the form of iron sulphide, FeS, which has had the name Troilite given to it. It occurs usually in separate rounded masses, which not infrequently attain the size of walnuts. In the meteorite of Cosby's Creek a piece weighing 200 grammes was noted. Iron sulphide always occurs in meteorites, but in quantity it varies very greatly, and its distribution is extremely irregular.

Silicon has only rarely been found in meteorites, but silicates and small crystals of quartz are often found, though of microscopical dimensions.

Chlorine has been found in the form of ferrous chloride. In the Knoxville and other meteorites crystals of it have been found filling cavities in the mass.

With regard to gases, the first experiment made to ascertain whether gas was occluded in them was made by Boussingault in 1861, who found in the Lanarto meteorite 0·0103 per cent. of nitrogen, while a Krupp steel examined at the same time contained 0·022 per cent. A more detailed investigation into the question was made by Wright, who found hydrogen, nitrogen, carbon dioxide, and carbon monoxide. Flight subsequently found marsh gas. The quantity of the gas found varies very greatly, too, as does its composition. This latter will be seen from the following, which relates to the gases found in nine different falls:—

	Per Cent.
Hydrogen	18·19 to 85·68
Carbon dioxide	0·00 to 14·40
Carbon monoxide	4·46 to 67·71
Nitrogen	0·00 to 17·66
Marsh gas	0·00 to 4·55

Hydrocarbons and similar compounds exist in meteorites, and have been frequently observed.

Passing from the consideration of the various constituents existing in meteorites, the author next considers the question as to how meteoric

iron may be distinguished from other varieties. Apart from its contents of nickel, a meteorite has always an oxydised exterior, and almost always a particularly marked structure. The Widmannstätten markings obtained on etching are well known. With regard to the actual quantity of meteoric iron that is now known, the author adds up the weights of seventeen of the larger meteorites, and the total weight of these amounts to over 182 metric tons. The author agrees with Sir Henry Bessemer in thinking that in former civilisations meteoric iron has been worked up largely wherever found.

In his concluding remarks the author observes that meteoric iron appears to have at one time been in a state of fusion, in which, as it subsequently solidified, liquation ensued, just as in the case of the manufactured metal. It would seem, though, that before cooling the metal had been heated to a temperature far above its melting-point, and that the cooling was very rapid in character. He even thinks it not impossible that the metal may have passed direct from the gaseous to the solid state. The ground mass of the meteoric iron is a nickel-iron alloy, and its properties vary with increasing percentages of nickel, just as is the case with artificial alloys of iron and nickel. It is interesting, the author observes, to note that alloys containing 60 per cent. of nickel, which are not as yet in use in practice, form a very malleable material that resists strongly the action of acids. The author suggests that if it is desired to produce a very strong material, a hint might be taken from these natural alloys by packeting together alternate layers of malleable nickel-steel and very soft iron, and then rolling out these packets in the ordinary way, just as has already been done in the case of chrome steel.

Numerous references to past work accompany this paper, and the whole subject has been treated in considerable detail.

E. A. de Schweinitz * describes a meteorite weighing about 50 lbs. which was ploughed up about three years ago in the south-west portion of Forsyth County. No characteristic etching was produced on polished surfaces; preliminary analysis gave—

Fe.	S.	Ni.	Co.	P.
94·90	0·22	4·18	0·33	trace

From this it would seem to be closely allied to the Guilford County meteorite, possibly a chip of the same find.

According to W. Huntingdon,† three masses, weighing about 7, 15, and 65 lbs., were ploughed up in 1892 near Smithville, De Kalb

* *American Journal of Science*, vol. i. pp. 208–209.

† *Proceedings of the American Academy*, vol. xxix. pp. 251–260.

County, Tennessee; they closely resemble the Cocke County iron. The iron shows a marked octahedral cleavage, and encloses nodules of troilite embedded in graphite and schreibersite; small crystals of cliftonite, and perhaps also diamond, are present. Analysis gave—

Fe.	Ni.	Co.	Cu.	P.	Residue (mainly Cliftonite).	Total.
91·57	7·02	0·62	trace	0·18	0·15	99·54

This analysis is compared with those of other irons from Tennessee and West Virginia, and it is pointed out that many of these may have originally formed part of the Cocke County fall.

According to A. F. Renard * a meteorite, weighing nearly 4½ lbs., fell at Lesves, in Belgium, on 13th April 1896, burying itself 40 centimetres in the ground. Analysis by Stöber gave—

SiO_2.	Al_2O_3.	Cr_2O_3.	FeO.	CaO.	MgO.	K_2O.
39·46	3·33	1·02	15·82	1·54	22·75	0·09
Na_2O.	Fe.	Ni.	Co.	S.	Total.	Sp. gr.
1·05	12·36	1·37	0·11	2·25	101·15	3·575

The mineralogical composition is given as—

Olivine ($Fe_2SiO_4+2\frac{1}{2}Mg_2SiO_4$).	Bronzite ($FeSiO_3+3MgSiO_3$).
45·88	22·33

Nickel and cobalt iron.	Troilite (FeS).	Chromite.
9·91	6·18	1·51

Maskelynite and a monosymmetric pyroxene are also probably present. The structure is chondritic, and both the crystals and the chondrules of olivine and bronzite contain glassy and other enclosures. Under the microscope, the olivine shows undulose extinction, and a fragmentary structure; it is, therefore, considered that the paste of the meteorite is a product of cataclastic action. In the crust three zones can be distinguished.

According to R. C. Hills † the Costilla meteorite, which weighs about 78 lbs., was found, in August 1881, on the north slope of Costilla peak, about six miles south of the boundary-line between Colorado and New Mexico. The etched surface shows bands of kamacite and tænite parallel to the octahedral cleavage. A little troilite, schreibersite, and a substance like graphite are present. An analysis by L. G. Eakins gave—

Fe.	Ni.	Co.	P.	S.	Total.
91·65	7·71	0·44	0·10	0·26	100·16

* *Bulletin de l'Académie Belge*, vol. xxxi. pp. 654-663.

† *Proceedings of the Colorado Scientific Society*, vol. v. p. 2; *Journal of the Chemical Society*, vol. lxx. p. 614.

Iron and Manganese Ores in Bukowina.—The southern portion of Bukowina is rich in ores of iron, manganese, and other metals,* and iron ore was mined around Jakobeny more than a century ago. A blast-furnace was subsequently erected there. The manganese ores mined are of excellent quality. The following are some analyses of the ores:—

(1.) Magnetite from the Rusoja mine:—Fe_2O_3, 60·58; FeO, 16·50; gangue, 37·00, and traces of lime.†

(2.) Spathic carbonate from the Coloko mine:—Fe_2O_3, 67·78; $MnCO_3$, 12.51; FeS, 1·67; $CaCO_3$, 2·08; $MgCO_3$, 1·30; and gangue, 14·19 per cent.

(3.) Brown iron ore from Paren Timi:—Fe_2O_3, 75·48; Al_2O_3, 7·27; S, 0·11; gangue, 3·75.

Other ores contained:—

Mine.	Iron.	Manganese.	Phosphoric Anhydride.	Gangue.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Upper Arschitza . . .	13·00	27·16	1·54	34·88
Anna	12·28	36·26	1·09	19·84
Theresia	4·45	46·73	0·86	13·56
Schara	5·08	45·43	0·67	17·82

A psilomelane from Arschitza contained:—

	Per Cent.
MnO_2	72·20
MnO	8·90
Fe_2O_3	10·00
$Ca_3(PO_4)_2$	1·57
H_2O	2·60
SiO_2	4.75
Total	100·02

Its specific gravity was 4·364.

A sample of ferro-manganese made at the Jakobeny blast-furnace from the "black ironstone" of that neighbourhood contained:—

Iron.	Manganese.	Phosphorus
77·01	9·82	4·82

Manganese Ore in Russia.—Manganese ore ‡ occurs in Russia in the Ural Government of Ekaterinoslav and in the Caucasus. The Cau-

* *Chemiker Zeitung*, vol. xx. pp. 611–612; *Stahl und Eisen*, vol. xvi. p. 651.

† There appears to be an error in the original in these results.

‡ *Vistnik Finansoffe*, No. 28, 1896. Abstracted by Mr. G. Kamensky, Assoc. R.S.M.

casian mines are most numerous, and the richest are situated in the Sharopansk district along the River Koirill, 25 miles distant from the Poti-Tiflis railway. The ore occurs in beds in Eocene limestone, lying upon chalk and covered by siliceous limestones and sandstones of Upper Eocene age. The beds of ore and the strata containing them lie almost horizontal, and form a mountain plateau, which is deeply cut almost through the centre by the River Koirill and its lateral ravines. Owing to this contour, the strata lie bare along the precipitous sides of the river valley and ravines, frequently appearing as almost perpendicular walls of limestone and sandstone, at the summit of which continuous black seams of manganese ore are seen to run. The presence of ore has been proved over an area of 126 square versts (55·334 square miles). The thickness of the seam of ore varies between 0·7 and 1·2 sagen (4·9 and 8·4 feet). The sorted ore contains not less than 50 per cent. of manganese; the average contents of phosphorus being 0·16 to 0·7 per cent. The ore is worked by levels 1·5 to 2 sagen (10½ to 14 feet) wide, driven at short distances along the outcrop, for a length of 50 to 60 sagen (350 to 420 feet), and then by working away the masses between the different levels by cross-cuts, leaving pillars to support the roof. Owing to the soundness of the roof and floor, hardly any timbering is required. The presence of thin seams of clay and soft ore among the ore enables it to be worked without the use of explosives. The ore is carried from the mines to Chiatura, the nearest railway station, by horses and in carts, at a cost of 1½ to 3½ copeks per pood (1s. 10¼d. to 4s. 4d. per ton). The mines pay a royalty of 0·66 to 1·32 copeks per pood (7½d. to 1s. 8¼d. per ton) of sorted ore, so that at Chiatura it comes to 5 to 6½ copeks per pood (6s. 2½d. to 8s. 0½d. per ton). The export of manganese ore from Russia has risen from 35,464 tons in 1885 to 163,014 tons in 1895.

Chrome Iron Ore.—The greater part of the world's supply of chrome ore comes from Russia and Turkey. In Quebec, there is no doubt that a large quantity of chrome ore exists, and that a flourishing industry can be built up in the Black Lake district. These deposits are fully described by M. Penhale.*

The occurrence of chromite in Austria and Hungary is described by R. Helmhacker.† Among the Austrian dependencies, Bosnia now takes the first rank in the production of chrome iron ore. Typical analyses

* *The Mineral Industry*, New York, vol. iv. pp. 92-93.
† *Ibid.*, pp. 94-96.

of hand-picked ores (1), and of crushed and separated ores (2), show the following composition :—

	Cr_2O_3.	FeO.	Al_2O_3.	MgO.	CaO.	SiO_2.
1. . .	59·2–50·2	33·0–17·2	5·3–13·0	1·1–12·7	1·8	1·0–13·0
2. . .	43·0–49·0	30·5–21·2	6·5–16·0	1·5– 9·3	3.2	1·5– 4·0

Mining industry in Turkey * has hitherto been much neglected, and it is only during the last few years that permission has been granted to sink shafts. This has led to a considerable increase in the output of ores of all kinds. The *Montan und Metall Industrie Zeitung* says that this is especially the case with respect to chrome ore, which is worked on a large scale in the vilayet of Kossovo, where it exists in considerable quantities, being chiefly exported to Germany and Great Britain, and in a less degree to Austria-Hungary, where it is treated especially at Hrastiugg in Carinthia. Up to 1894 the chrome mines were worked by the Ottoman Government without special authority from the Porte; and the small quantity of ore raised found a ready market. At the present time the chances in favour of working chrome mines are improved, on account of the concessions granted by the Turkish Government, which authorises the extraction, without firman, of 200 ten-ton waggon-loads on payment of a Government tax of nine Turkish pounds, with an export duty of half a Turkish pound per waggon (Turkish pound equals 18s.). When there is a firman the Government tax is reduced one-half, and there is no limit to the quantity which may be extracted. In 1895 Germany received through Hungary from Turkey, more than 8000 tons of chrome ore.

Nickel Ore in Oregon.—In a paper read before the Colorado Scientific Society, W. L. Austin described the nickel ore veins of Josephine County, Oregon. They are noteworthy as being the only deposits of nickel ore in the United States, with the exception of those in Nevada. Hitherto the extraction of the nickel from these ores has been found to be attended by great difficulty. Should, however, the ore prove to be present in sufficient quantity, and to be as rich as the assays indicate, the metallurgical difficulties will doubtless be overcome, as has been the case in New Caledonia and in Canada. Certainly the deposits are of special interest in view of the demand for nickel steel for armour plates.

* *Journal of the Society of Arts*, vol. xliv. p. 503.

The Valuation of Iron Ores.—G. Teichgräber * considers the question of a ready method for determining the furnace value of an iron ore. Considering its chemical composition, he observes that 1 part of silica requires on the average 2·5 parts of limestone for fluxing, and it forms then about 3 parts of slag. The higher the silica the greater will be the cost of smelting, and an endeavour should be made to have a material to treat which is as low as possible in this gangue stuff. The author adopts a formula in which—x is the price of an iron ore, f.o.b.; f, freight per 10 tons; e, percentage yield of pig iron; r, percentage of calcium carbonate in the ore; C, price of 10 tons of coke, f.o.b.; F, freight of 10 tons of coke; K, price of 10 tons of limestone delivered; v, consumption of coke for each 1000 kilogrammes of pig iron made, in kilogrammes; g, general costs per ton of pig iron; and P, cost of production of the ton of pig iron.

P is made up of the cost of the iron ore, the cost of the limestone, the cost of the coke, and general charges. From 10,000 kilogrammes of iron ore which, delivered at the works, costs $(x + f)$ shillings, are produced $\frac{10,000\,e}{100}$ kilogrammes $= \frac{e}{10}$ tons of pig iron. For one part of silica 2·5 parts of limestone are added as flux, deducting that which exists in the ore. For 10,000 kilogrammes of iron ore with r per cent. of silica and k per cent. of calcium carbonate, there is consequently required $100\ (2{\cdot}5\ r - k)$ kilogrammes of limestone as flux. From 10,000 kilogrammes of iron ore $100\,e$ kilogrammes of pig iron are produced, and consequently for $100\,e$ kilogrammes of pig iron $100\ (2{\cdot}5\ r - k)$ kilogrammes of limestone, or for 1000 kilogrammes of pig iron $\frac{1000}{e}\ (2{\cdot}5\ r - k)$ kilogrammes, which costs $(2{\cdot}5\ r - k)\ \frac{K}{10\,e}$ shillings.

With regard to the coke, for 1000 kilogrammes of pig iron v kilogrammes of coke is necessary, costing $v\ \frac{C + F}{10,000}$.

The total cost of 1000 kilogrammes of pig iron is therefore: $P = (x + f)\ \frac{10}{e} + (2{\cdot}5\ r - k)\ \frac{K}{10\,e} + v\left(\frac{C+F}{10,000}\right) + g$; and from this results the value x of an iron ore, if the cost of production of the pig iron made from it is P shillings: $x = \frac{Pe}{10} - f - \frac{K}{100}\ (2{\cdot}5\ r - k) - \frac{e}{10}\left(v\ \frac{C+F}{10,000} + g\right)$.

* *Stahl und Eisen*, vol. xvi. pp. 632–633.

Two samples of iron ore are taken as examples—one containing 48 per cent. of iron, 25 of silica, and 3 of calcium carbonate; and the other, 30 per cent. of iron, 12 of silica, and 40 of calcium carbonate.

For the first of these the calculation would be: $x = \frac{49 \cdot 48}{10} - 30 - \frac{33}{100}(2 \cdot 5 \times 25 - 3) - \frac{48}{10}\left(900 \times \frac{115 + 35}{10,000} + 5\right) = 96 \cdot 765$ shillings.

For the second the calculation shows: $x = \frac{49 \cdot 30}{10} - 30 - \frac{33}{100}(2 \cdot 5 \times 12 - 40) - \frac{30}{10}\left(900 \times \frac{115 + 35}{10,000} + 5\right) = 64 \cdot 80.$

The author observes that from this it is evident that under certain conditions an iron ore, poor in iron, may be just as valuable a material as one of higher percentage. The above, of course, only affords a ready means of determining the approximate value, a number of other factors also affecting the real value.

II.—*IRON ORE MINING.*

Exploring with the Diamond Drill.—T. W. Gibson * states that the Legislature of Ontario provided for the purchase by the Government of two diamond drills. One of these has been acquired and used at several places in the province for exploratory drilling for ores and minerals. The Bureau of Mines bears 45 per cent. of the charges, and those employing the drill bear the remainder. The first property at which the drill was used was the Glendower Iron Ore Mine, situated at Bedford, in the county of Frontenac. After 75,000 tons were taken out the ore became too sulphurous, but drilling seemed to show better ore in depth. The drill was therefore employed to test the matter, and several holes were put down through the ore body at different angles and places, with the result that very considerable bodies of good ore were found to exist between masses of mixed ore. Six borings were made, aggregating 2626½ feet in depth, at the average rate of 14½ feet per working day, at a total cost of about £520. Since then the machinery has been used on other properties. The cost of boring at these places and in other countries is then considered.

Notes on prospecting with the diamond drill are also given by

* *Journal of the Canadian Mining Institute*, vol. i. pp. 197–213.

J. Parke Channing,* together with the costs of the operations at various iron ore mines in Minnesota and Michigan.

Lake Superior Iron Ore Mining.—In a lecture on engineering as exhibited on the Great Lakes, J. Birkinbine † dealt at length with the working of the Lake Superior iron ores. The industry dates from 1856, when the first iron ore was shipped from Marquette. As new fields were discovered and new mines opened, markets were found for the increased outputs, and nearly 10½ million tons were sent from the mines of the Lake Superior region in 1895. Some of the machinery at these mines is of the latest type. The Chapin mine, for example, has a vertical compound pumping engine, with cylinders 50 inches and 100 inches in diameter and 10-feet stroke, designed to deliver 3000 gallons per minute from a depth of 1500 feet. The plunger pumps, 28 inches in diameter and 10-feet stroke, are connected to the engine through a horizontal beam, and also to a 40-foot flywheel weighing 160 tons. The methods of mining the Lake Superior iron ores vary, according to the character of the deposit, from excavating with the steam shovel to working with rock-drills 1450 feet below the surface. The following is a statement of the cost of mining one ton of ore at one of the large iron mines from a depth of 500 feet:—

	s.	d.
Actual mining cost (including labour), explosives, light, &c.	1	10
Timbering	0	3
Machinery and office expenses	0	3
Repairs	0	1½
Loading and sorting ore	0	1½
Insurance and other expenses	0	1½
Total for ore loaded on trucks	2	8½

This was an ore of medium hardness, and the quantity of water handled was not excessive.

F. W. Denton ‡ describes the method of mining adopted in the Lake Superior district, discussing the work of the removal of the deposit, and the considerations which should influence the establishment of a method of mining.

The Lake Angeline Mines.—Under the bed of Lake Angeline, which was drained some four years ago, there are now three companies

* *The Engineering Magazine*, vol. x. pp. 1074–1092.
† *Journal of the Franklin Institute*, vol. cxli. pp. 428–447; vol. cxlii. pp. 42–51.
‡ *Engineers' Year Book*, University of Minnesota.

at work. There is a plentiful growth of vegetation on the mud; but beneath it is very watery and mobile, and in parts it attains a depth of 15 to 40 feet. The first level of the Cleveland Lake mine is at a depth of 150 feet, leaving a good mass of ore to keep out the mud. At the north-west of the lake some work is prosecuted on the caving plan, where the ore is 115 feet thick. The surface has settled evenly, and mud has kept out of the mine. At the Salisbury mine there has been much settlement of the surface, and a new shaft will have to be sunk. Electric haulage has been adopted in these mines.*

A more recent note states † that mud has broken into one of the mines. It is too soft to work with shovels, and not liquid enough to pump.

Winding Appliances.—T. F. Cole ‡ describes the winding-plant employed at the Prince of Wales iron mine in the Lake Superior region. The engine is now raising 800 tons of ore daily from a depth of 450 feet, the cages being run in balance.

An illustrated description has been published of ore hoisting and conveying machinery at Ashtabula, Ohio.§

Rock-Drills.—H. Drolz || observes that at the Bindt iron ore mines an electric rock-drill plant was put into operation in May 1894. He gives details as to its subsequent use, and shows that the cost per metre driven averaged 25 florins 84 kreuzer, and the cost per bore-hole one metre in depth averaged 54·27 kreuzer over a period of one year (or about forty shillings and tenpence per yard respectively). The drills, which are on the Marvin system, have given satisfaction. It is by one-half lighter than the Depoele drill, is simpler, and has a greater throw. In electric drills too much importance is generally attached to power consumed. It is inaccurate to make this the chief consideration. The Marvin drill has given satisfaction under very varying conditions.

The use of rock-drills continues to spread in the mines of Prussia.¶ The new machines and air-compressors laid down in 1894 did not differ

* *Iron Trade Review*, vol. xxix. No. 35, p. 10.

† *Iron Age*, vol. lviii. p. 492.

‡ *Engineering and Mining Journal*, vol. lxii. p. 220.

§ *Engineering News*, vol. xxxvi. p. 114.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 484–488, 501–503, with seven illustrations.

¶ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliii. p. 187.

in type from those already in use. In the Clausthal district it has been found that the substitution of rock-drills for hand-drilling has resulted in a saving of 50 per cent. in the costs, while the work progresses three times as fast. At one mine when drilling uppers it has been found desirable to sprinkle the hole with water during the drilling, to diminish the large quantity of dust that is produced. A special apparatus is used for the injection of the water. This consists of a water-tank placed on wheels, and provided with an indiarubber tube which admits of connection with the compressed air supply, and another such tube which passes into the borehole, and through which the water is ejected from a spray nozzle by the action of the compressed air above the surface of the water. To reduce the quantity of dynamite used at one of the mines the diameter of the hole drilled was slightly lessened, with the result that a saving of some 20 per cent. can be effected. Valves kept tight by the use of leather have been used successfully, instead of cocks in connection with parts of the compressed air conduits. In addition to the Fröhlich-Jäger drill the Hoffmann drill was also frequently employed in the Siegen district. This latter machine differs somewhat from other drills, and is stated to give better results in hard rock. Air compressed to five or six atmospheres has been successfully employed at the Reden mine near Saarbrücken. The use of the Fröhlich drill at this mine shows that, as compared with hand-drilling, machine-drills are just as dear in sandstone and similar country, and dearer in shale and coal, but cheaper in conglomerate and other hard rock. On the other hand, in soft country the progress made is five or six times as rapid, while in hard rock it is as much as from ten to fifteen times. The stronger charges in the machine-drilled holes necessitate subsequently walling instead of ordinary timbering in soft country.

Pelton Motors.—These well-known motors are described with the aid of two illustrations by J. Ritter von Hauer.*

Electric Haulage. — J. E. Jopling † describes the electric locomotive haulage at the Cleveland Lake mine. A 115 horse-power Corliss engine drives a direct current multipolar generator at 650 revolutions, to give a current up to 300 amperes at 220 volts. Overhead conductors supply current to the locomotives, of which there are

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 147.

† Paper read before the Lake Superior Mining Institute, through the *Iron Trade Review*, vol. xxix. No. 35, pp. 12-13.

two. The gauge of the rails is 30 inches, and the minimum curve has a 42-feet radius. The motor on the first level is a 65 horse-power machine on four 24-inch wheels. Its weight is now nine tons, its speed is six miles per hour, and it will draw a load of 50 tons. The motor in the second level runs at 10 miles per hour with a 25-ton load. It is a 30 horse-power machine on four 30-inch wheels, and it weighs seven tons. Details of the costs are appended, and the cost of haulage is given as 2·4 pence per ton.

E. F. Bradt * describes the electric locomotive haulage at the Lake Angeline mine. Steel rails 30 lbs. to the yard, with fish joints, are laid on sleepers spaced two feet apart. The gauge of the line is 30 inches. The locomotives are rated at 30 horse-power; they run at six miles per hour, and give a drawbar pull of 1500 lbs. Their width is 51 inches, length 10¾ feet, height 32 inches, and total weight 9000 lbs. Current is supplied by an 85 horse-power Thomson-Houston generator, running at 900 revolutions, and giving 110 amperes at 110 volts. It is led to the locomotives by an overhead conductor. Curves are easily rounded, and the average train is composed of four to six trucks carrying two tons each. The cost of the plant and particulars of the working expenses are appended. Haulage cost was given as 4·69 pence per ton.

Ancient Mining.—A. Cooper Key † has compiled a large amount of information regarding ancient mining. He treats of Egyptian surface working and mining, mines in Asia, and Phœnician mining.

Early Iron Ore Mining in Michigan.—W. P. Kibbee ‡ gives a short historical sketch of the iron ore industry in Michigan. The discovery in the upper peninsula was made in September 1844, by a party of surveyors who noticed remarkable variations in the magnetic needle. In the following year the first location of iron ore lands was made, and this included the present Jackson mine. Much of the land was speedily taken up, but for many years there were great disputes as to the rights possessed by different parties. The first iron made on Lake Superior was in a forge on Carp river in 1848, and for some time the daily product was three tons; but the execrable roads and other diffi-

* Paper read before the Lake Superior Mining Institute, August 18, 1896, through the *Iron Trade Review*, vol. xxix. No. 36, pp. 14–15.

† *Mining Journal*, vol. lxvi. pp. 627, 659, 734, 822.

‡ *Iron Age*, vol. lvii. pp. 1474–75.

culties caused its abandonment by 1856. Besides the Jackson mine the Cleveland and the Lake Superior mines are the oldest in the district, and still continue to be the most important. It was soon seen that the ore would find its market in the coal districts of Pennsylvania and Ohio. A railway was contracted for in 1853, and was put into operation in 1857, and the Sault Canal was completed in 1881. The author then traces the rapidly increasing output of these districts.

III.—*MECHANICAL PREPARATION.*

The Wetherill Method of Magnetic Separation.—H. A. J. Wilkens and H. B. C. Nitze* give an illustrated account of the Wetherill magnetic separation, about which numerous statements have appeared of late with regard to their power of separating non-magnetic material. As a matter of fact, they are used for treating material of which the magnetic permeability is so low, that, as a rule, it is spoken of as non-magnetic. Such materials are hæmatite, limonite, siderite, rutile, franklinite, and others. The special features of the machine are that the pole pieces are shaped so as to concentrate the lines of force, and are surrounded by moving belts which carry away the attracted material. The ore is fed in a uniform layer upon travelling bands from hoppers which are provided with adjustable feed. The bands pass over pulleys and electro-magnets which have tapering pole pieces, and are adjustable towards or away from each other by means of screws. Beneath the pole pieces are three receptacles, a middle one with adjustable leaves for receiving the non-magnetic substance, and two outer receptacles for receiving the magnetic material. Sometimes one only of the pole pieces is made tapering. In another form there are two magnets giving two magnetic fields formed between poles of the separate magnets, and the feeding belts are inclined towards the pole pieces so as to pass over their extremities.

The authors then give the results of a number of tests made with various ores. Amongst these are the franklinite ores of New Jersey, and the Clinton fossil ores of the Birmingham district, Alabama. Manganese ores have also been treated with success.

* *Transactions of the American Institute of Mining Engineers;* Pittsburgh meeting (advance proof). *Iron Age*, vol. lvii. pp. 1420–21. *Engineering and Mining Journal*, vol. lxi. pp. 564–565.

W. B. Phillips* discusses the subject of the concentration of iron ore. The weak part of the process of roasting the ore to magnetise it for subsequent separation lies in the difficulty of regular and uniform magnetisation. This was foreseen in regard to the Clinton ore, and it cannot be said that practical success was attained. The Wetherill process on an experimental scale gave good results without the previous magnetising roasting. The heads were not quite so rich as in the Payne separator, but the tailings were poorer. The use of the Payne machine ceased in order to save the expense of roasting, not because it did not work successfully. An account is then given of trials with the Wetherill separator, of which an extended series were made with ores from the Birmingham district under different conditions as regards fineness and richness, and of these the numerical results are given. The author is convinced that a ton of concentrates carrying 53 to 56 per cent of iron can be made from 1·75 to 2 tons of raw ore, and that the tailings will not carry more than 15 per cent. of iron; but it will require the most unremitting attention.

Sampling Iron Ore.—C. T. Mixer† describes the methods of sampling in use at some of the mines in the Marquette district. In the Lake Angeline mine each stope is sampled every other day by a special man detailed for the purpose. After the ore is hoisted, samples are taken from the trucks; but sampling at the shipping port is discontinued. At Cleveland Lake mine, the stopes are sampled every day, and a sample is taken every ten feet when drifting. Samples are also taken from the shoots. At Salisbury mine, reliance is placed on the skip samples. At the Lake Superior Company's mines, the stopes are sampled three times a week, and stock pile samples are also taken. At the Negaunee mine and at the Queen mine, each set of men have two places to work in, occupying one whilst the other is being sampled, so that the quality of the broken ore is determined before it is removed. At the Champion mine but little sampling is required, except there is some irregularity in the output.

* *Engineering and Mining Journal*, vol. lxii. pp. 105, 124.

† Paper read before the Lake Superior Mining Institute, through the *Iron Trade Review*, vol. xxix. No. 35, pp. 10–12.

REFRACTORY MATERIALS.

Conductivity and Expansion of Fire-Brick.—J. D. Pennock * gives the results of some experiments on the heat conductivity, expansion, and fusibility of fire-brick. For the determination of the conductivity, cylinders of different kinds of fire-brick carefully insulated were heated simultaneously at one end, and the rise of temperature at the other end was taken at intervals by thermometers. The expansion was determined by a set of multiplying levers abutting against a heated cylinder of the material. It ranged from 0·11 inch to 0·076 inch in 12 inches in three varieties of refractory material. Analyses of the substances used are given with the numerical results of each experiment, but the values are not compared with known factors.

Refractory clays and fire-brick are discussed by C. Ferry, † his essay being illustrated by drawings of the pug-mill, brick-making machine, hand-press, up-draught kiln, down-draught kiln, and continuous kiln.

The Seger Scale.—H. Hecht ‡ has determined the melting-points of various fire-clays of the Seger scale by means of the Le Chatelier pyrometer. He finds that the most fusible one melts at 590° C., No. 09 at 970°, No. 04 at 1070°, No. 10 (melting-point of felspar) at 1330°, No. 20 at 1530°, and No. 36 at 1850°. The melting-points above 1500° are, however, uncertain.

Dolomite from Graz.—Specimens of dolomite rock from the Schloss-berg at Graz, examined by J. A. Ippen, § gave the following results on analysis :—

$CaCO_3$.	$MgCO_3$.	$FeCO_3$.	Insol. (SiO_2).	H_2O.	Totals.
53·27	41·77	1·63	1·42	0·96	99·05
55·07	41·78	1·44	1·26	0·64	100·19
55·10	43·93	trace.	0·30	not det.	99·33

* *Transactions of the American Institute of Mining Engineers*, Colorado Meeting (advance proof).

† *The Mineral Industry*, New York, vol. iv. pp. 113–122.

‡ *Thonindustrie Zeitung*, vol. xx. p. 293.

§ *Mittheilungen. Naturwissenschaftlicher Verein für Steirmark*, vol. xxxi. pp. 272–275.

Bauxite.—W. M. Brewer * discusses the bauxite industry of the United States. New discoveries of deposits of the mineral are recorded. Until 1895 no effort was made to wash or to dry the ore mechanically. A Georgia company has, however, erected a Davis-Colby kiln for this purpose. This company also washes some of the mineral. The massive structure of most of the bauxite in the mine renders the use of a washer in ordinary circumstances unnecessary.

Graphite Crucibles.—Some interesting statistics regarding the production of crucibles in the United States have been published by R. Helmhacker.† There are in the United States eleven works producing crucibles, used chiefly for steel-melting. In Massachusetts there are two establishments, employing twenty-seven workmen, and producing, from £7920 worth of raw material, crucibles to the value of £13,700. New Jersey has two works, employing 572 workmen, and producing, from £96,400 worth of raw material, crucibles to the value of £160,000; whilst Pennsylvania has seven works, employing ninety-two men, and producing, from £86,800 worth of raw material, crucibles valued at £115,400. The industry thus affords employment to 691 workmen, and produces crucibles to the value of £289,100.

There are only three graphite mines at work in the United States; and, as the best graphite is used for the manufacture of black-lead pencils, the supply of graphite for crucible manufacture is drawn largely from Canada. The Canadian graphite is fairly pure, containing, as it does, 76·4 to 88·5 per cent. of carbon, 23 to 10·4 per cent. of ash, and 5 to 7 per cent. of moisture. As the Canadian supply is not sufficient for the purpose, European graphite is also largely used.

* *The Mineral Industry*, New York, vol. iv. pp. 49–50.
† *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 79.

FUEL.

CONTENTS.

I.—*CALORIFIC VALUE.*

Pyrometry.—J. Wiborgh * divides pyrometers into five classes: (1) Those which depend on the expansion of solid, liquid, or gaseous bodies by the action of heat; (2) those in which temperature determinations are made by the calorimeter or hydropyrometer; (3) those which depend on the different melting-points of various substances; (4) electric pyrometers; and (5) optical pyrometers.

The first class, depending on the expansion of a body, includes many pyrometers. Steine and Hartung, Gauntlett and others, compare the expansion of a rod of graphite with that of a metallic tube heated to the same temperature. When the expansion of solids is employed, there is a second sub-class in which a strip of one metal is attached to a strip of another, and the whole wound in the form of a spiral, and so placed in a cylinder that one end becomes fixed, whilst the other can be attached to an indicator. These forms of pyrometer are, however, only of use in the determination of temperatures of 300° to 400° C. The cause of this lies in the fact that at high and long-continued temperatures metals undergo changes of texture with the result that their co-efficients of expansion also change.

In the use of liquids instead of solids it has been found possible by filling the upper part of a mercury thermometer with nitrogen under pressure to register temperatures of from 450° to 500° C. Attempts

* *Jernkontorets Annaler*, vol. li. pp. 102-128.

have been made to measure the pressure of the gas which results when a liquid is heated to a high temperature in a closed vessel, but this form of pyrometer has met with no success in practice. On the other hand, greater success results when the expansion or tension of "permanent" gases is utilised, and on this the air pyrometers depend. They are the most accurate of all pyrometers; but it is difficult to produce such an instrument that shall be of value in practice, for various corrections have to be made, and the instrument becomes complicated, or the reading difficult. The vessel, too, that contains the air, can only be made of porcelain. The author's own pyrometer, based on this principle, is, he says, simple in construction, and is coming more and more into practical use. It cannot, however, be used for temperatures exceeding 1300° or 1400° C., as the porcelain tube soon becomes useless.

The second class of pyrometers, in which calorimetric measurements are made, is well known, and in them it has to be assumed that the specific heat of the substance heated, usually copper, iron, or platinum, remains constant; but this is not the case at high temperatures, with the result that the methods become less accurate under these conditions. To this class can also be added the Hobson pyrometer, mainly designed for use in connection with blast-furnaces, and in which the hot blast streams out through an injector, sucking the external air with it, the temperature of the air-mixture being then measured by a mercury pyrometer. This instrument is easy of manipulation; but its accuracy is affected by a number of conditions, such as pressure of blast, temperature of the external air, &c.

The third class of pyrometers, depending on variation in the melting points, is old in its application and widespread in its use. The melting points of the various metals have been determined, and the melting points of salts and alloys are also known. Only silver, gold, and platinum, the author states, melt at constant temperatures, while the other metals and the alloys yield uncertain results. In furnaces, such as porcelain ovens, which are slowly raised to a definite temperature, the Seger cones, made of mixtures of quartz, felspar, kaolin, and marble, give useful results and are much used.

The electrical pyrometers, forming the fourth class, include those of Siemens and of Le Chatelier. These have been so often described in the *Journal of the Iron and Steel Institute* that they need not be further described here.

The fifth class, or optical pyrometer, is next described, the author considering the Mesuré-Nouel pyrometer to be the best of this class.

The change in the colour and other sources of error render this pyrometer only useful for special cases, and when used by one and the same person.

For the determination of high temperatures Wiborgh has designed a new method of pyrometry. A small quantity of explosive material is hermetically sealed in a suitable envelope, and is then placed in the centre of a body of a refractory material, which thus becomes the "thermophone." This is then cast into the furnace, of which the temperature is to be ascertained, the temperature being determined by the lapse of time before the explosion occurs. A table has been prepared giving the degrees of heat corresponding to different intervals of time, by permitting thermophones to explode at known temperatures, and by observing the lapse of time in each case; by this table it is possible to ascertain the temperature corresponding to an observed interval of time.

H. Wedding * discusses the use of the Le-Chatelier-Heräus pyrometer in iron metallurgy. Passing other systems in review, he first refers to the Siemens electric pyrometer, then the Gauntlett expansion pyrometer, and next the Seger cones. None of these methods, he adds, can be used for the determination of the temperature of red-hot or fused metals, but only for the determination of the temperature of the space in which the heating is being effected, that is to say, for the measurement of the temperature of heated gases. These are the kinds of pyrometric methods that have been available in the past, and it follows, therefore, that extremely few reliable determinations have been made of the temperature of heated iron, especially of malleable iron in rolling or pouring; and yet the importance of a knowledge of these temperatures cannot be called in question, as the success of the operation is dependent on the temperature at which it is effected. Still more important, again, is a knowledge of the temperature of the ingot metal used in making castings, and the author observes that the investigations of Holborn and Wien possess, therefore, much importance. They found that of all the pyrometers that had been proposed up to the date of their experiments, only those of Siemens and the thermo-electrical pyrometer were of value for the accurate determination of high temperatures. The resistance pyrometer of Siemens is, however, of no value for very high temperatures, as no material is known which is sufficiently isolating under these conditions, and for this and other reasons this pyrometer is unsatisfactory. They next compared the Le Chatelier pyrometer with an air thermometer, and examined into the question of the best alloy to be

* *Stahl und Eisen*, vol. xvi. pp. 660–665.

employed in the couple, the percentages of rhodium being greatly varied. They found that a 10 per cent. alloy was approximately as satisfactory as any with a higher percentage of rhodium. With a lower percentage of rhodium, however, the results were not so good. The use of this pyrometer was found less satisfactory for low temperatures than for higher ones. The author describes the pyrometer at some length, and the method of using it. By adopting certain precautions the instrument could be employed uninterruptedly a whole day in a welding furnace, the temperature of which varied from 1150° C. to 1200° C., despite the fact that it was frequently inserted rapidly and withdrawn. The variations in the temperature of the furnace were readily detected. Thus after stirring the temperature always fell from about 1140° to 1115° C. The temperature of blast-furnace slag was found to be 1450° C.; but in making this determination a curious accident occurred. There was a sudden explosion which blew off the end of the tube, and the pyrometer had to be withdrawn as rapidly as possible from the slag stream. This explosion could only have been due to a small quantity of moisture which may have penetrated into the tube used. For measuring the temperature of molten pig iron or ingot metal, porcelain protecting tubes cannot be used, as they break; nor iron ones, as these melt; while tubes of nickel or of platinum dissolve in the bath of molten metal. The ordinary method suitable for the measurement of the furnace temperature is also inapplicable. The author has endeavoured to find a means of meeting this difficulty, and of enabling the pyrometer to be dipped vertically into the bath like an ordinary thermometer into water. For this purpose a porcelain or clay pipe is expanded at the end into a bulb or wide cylinder. The lower portion of this is filled with powdered metallic tungsten, mixed with charcoal that has been made red-hot before admixture. The use of this charcoal is to prevent the possibility of the tungsten sintering together. On the top of this is placed an asbestos plug, and then the thermo-couple, well protected by asbestos packing, which fills the whole of the free space, a darning-needle being used at first to keep a space free through which the entangled air can escape. An asbestos covering is then placed over the porcelain bulb, and bound in place by asbestos thread. This arrangement has the great advantage that, owing to the high specific gravity of the tungsten, the instrument can be lowered vertically into the molten bath.

G. Braubach * describes a pyrometer for the determination of the temperature of the blast in blast-furnaces. It consists of a water-tank

* *Stahl und Eisen*, vol. xvi. pp. 572-573, with one illustration.

which will hold some 30 or 40 litres of water. Through this, water is constantly flowing, and is maintained at a constant level by means of an overflow pipe. From the bottom of this tank pass two small pipes. One of these passes right across the outer end of the tuyere, and consists at this point of a copper tube of 8 millimetres internal diameter. Through this tube water passes and is heated by the hot blast passing around it. The temperature of the water is determined by means of a thermometer. The second tube leads from the bottom of the water-tank to another thermometer, which consequently shows the temperature of the water before it is heated by the blast. The two thermometers being placed side by side, the difference between them can at once be seen, and, after calibration, the actual temperature of the blast can be readily shown. The author recommends making one degree difference between the two thermometers represent 100° C.*

W. J. Waggener † has made a detailed study of the Bunsen flame with the aid of the Le Chatelier pyrometer, and finds that 1770° C. is the highest temperature of the flame.

II.—*COAL.*

The Yorkshire and Nottinghamshire Coalfield.—W. S. Gresley ‡ offers some geological suggestions relative to the eastward extension of the Yorkshire and Nottinghamshire coalfield beneath the Permian and Secondary strata into Lincolnshire. It is proposed that two boreholes should be put down about ten miles north-east of Lincoln and of Horncastle.

G. E. Coke § discusses the southern limit of the Nottinghamshire coalfield, and shortly describes the different boreholes, especially the Ruddington borehole, of which particulars have not previously been given.

The Eastern Limits of the Midland Coalfield.—E. Hull || discusses, in view of the facts brought to light by recent borings,

* This pyrometer does not appear to differ in principle from that of Carnelley. See *Journal of the Iron and Steel Institute*, 1884, No. I. pp. 195–196.

† *Annalen der Physik*, vol. lviii. p. 579.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 143–155.

§ *Ibid.*, vol. xi. pp. 339–344.

|| *Ibid.*, vol. xi. pp. 9–20.

the eastern limits of the Midland coalfield, dealing more particularly with the Leicester and Warwickshire districts. The result of the latest investigations is to reduce still further the possible area; and, in conclusion, the author states that it will be inferred from the evidence that the old Cambro-Silurian rocks formed a ridge trending from Shropshire and Worcestershire eastwards into the eastern parts of the counties of Warwick and Leicester, which was very irregular in its outline, and sent out ridges in a northerly direction separated by intervening bays. Against the shelving sides of these ridges the coal-measures were deposited, filling up the bays as the region gradually subsided under the Carboniferous waters, and in consequence the upper coal-measures cover a more extended area than the productive middle beds, and these than the Lower Carboniferous, which are altogether absent in South Staffordshire and Warwickshire.

W. J. Clarke * gives information concerning the Shropshire, South Staffordshire, and Wyre Forest coalfields, and explains difficulties that do not seem likely to be overcome. The probabilities of a continuous coalfield are consequently not promising.

The Pilsen Coal-Basin.—A. Weithofer † discusses the geological conditions of the Bayer shaft and of the neighbouring portion of the Pilsen coal-basin. Several seams of coal are met with. The main seam occasionally reaches a thickness exceeding six feet. The various fossils found are named, and the geological conditions of the district are dealt with in detail.

Tertiary Coal-Deposits near Bregenz.—The occurrence of Tertiary coals at the base of the northern slopes of the Austrian Alps, closely resembling the older bituminous coals, has long been known. The occurrence and method of mining of this Tertiary coal at Wirtatobel, near Bregenz, is described by W. von Gümbel. ‡ He discusses the origin of the coal geologically, and then historically reviews the mining in this district. The coal was worked in 1840; but in 1894 active mining operations were stopped, the main seam worked having split up into thin seams, and the price obtainable for the coal having considerably fallen off.

* *Colliery Guardian*, vol. lxxi. pp. 938–940.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 317–321, 331–335, 345–349, and 355–357, with plate.

‡ *Ibid.*, vol. xliv. pp. 115–121, with sheet of illustrations.

The Coal-Deposits of the Neograd District.—L. Maderspach * discusses a portion of this coalfield. Five boreholes have shown coal-seams varying in thickness from about twenty inches to ninety, and at moderate depths. The coal yields 5344 calories, and contains 12 per cent. of ash, and 2 of sulphur. About forty millions of tons of coal are stated to exist in the portion of the field he describes.

French Coalfields.—M. Coste † has published a geological study of the Villars coal-seam, and the faults occurring in the St. Etienne coalfield.

Chapuy ‡ gives some particulars of recent boreholes in the northern coal-basin of France; and J. Bergeron § discusses the possible extension of the different coalfields of France.

Coal in Norway.—It has long been known that bituminous coal occurs in Ando, the most northerly of the Loffoden Islands; but it is only recently that trial borings have shown that the deposits are workable. The seams are met with in the eastern portion of the island, and extend for a length of 5½ miles, and for a width of 2 miles. They rest upon granite, which has been struck at a depth of 140 yards. At the surface there is a peat-bog, 3 to 4 yards in depth, overlying the coal-seams, which alternate with layers of fine hard sandstone. In addition to coal, combustible peat, bituminous shale, bog-iron ore, and fire-clay have been found for the first time in Norway in this island. The island is provided with an excellent harbour for shipping the coal. ||

Coal in Spain.—During the recent visit of the Iron and Steel Institute to Spain, attention was called by A. Ajuria to the coal deposits of Sabero at the foot of the Cantabrian range, near the plains of the provinces of Leon and Palencia. The coalfield is long and narrow, the length being 10 miles. The seams vary from 1 to 24 yards in thickness, and the coal is well adapted for the manufacture of coke. On analysis the coal is found to contain 74 to 80 per cent. of fixed carbon, 20 to 26 per cent. of volatile matter, and 6 to 12 per cent. of ash. It is estimated that 56,000,000 tons of coal are available. Large quantities of rich iron ores occur in close proximity to the coal.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 500.

† *Annales des Mines*, vol. ix. pp. 608–621.

‡ *Comptes Rendus Mensuels de la Société dé l'Industrie Minérale*, 1896, pp. 47–48.

§ *Mémoires de la Société des Ingénieurs Civils*, vol. xlix. pp. 727–751.

|| *Zeitschrift für praktische Geologie*, 1896, pp. 415–416.

The Australian Coalfields.—L. Babu * observes that the coalfield of New South Wales, which extends from lat. 29° to lat. 36°, has an area of 62,000 square kilometres (about 24,600 square miles). The two most important mining centres are Newcastle and Wolongong, and the harbour of Newcastle is well equipped with wharves, hydraulic cranes, &c., and 25,000 tons of coal can be put on board ship daily. Hand-labour is very largely replaced in the collieries by machine-labour, and haulage is done by the tail-rope system, and at a rapid rate even on sharp curves. The waggons filled with coal are sent direct to the wharves, raised in hydraulic lifts, and tipped straight into the vessels.

Various New South Wales coals were examined by W. M. Doherty † for arsenic, but none was detected. Lead and copper were found in two instances.

Coal in Canada.—W. Henry ‡ describes the coal deposits of the North-West Territories of Canada, special attention being paid to the lignite deposits of the Souris Valley.

According to W. Pearce § the supply of coal in Manitoba and the North-West Territories is practically inexhaustible. Many years ago it was known that there were some 50,000 square miles of coal-area south of the 56th parallel of north latitude, exclusive of the lignites along Souris River. These coals range from lignite up to true anthracite. The latter occur between 50° 50′ and 52° 50′ north latitude and 115° 10′ and 116° 10′ longitude west of Greenwich, a large number of seams ranging from 2 to 10 or 12 feet in thickness. The quality of the coals improves towards the west.

A. McCharles ‖ states that coal has been found in the province of Ontario, where the formation is mostly of Laurentian and Huronian origin. In the trough between the two main nickel ranges there has, however, recently been found a patch of Cambrian formation about 10 miles wide and 40 miles long, extending north-east from the township of Trill almost to Lake Wahnapitae. In this strip, 15 miles west of Sudbury, anthracite has been found outcropping.

R. G. E. Leckie ¶ gives some notes on the Grand Lake coalfield of New Brunswick. This field is situated 70 miles north of St. John

* *Annales des Mines*, vol. ix. pp. 315–395.
† *Chemical News*, vol. lxxiii. pp. 191–192.
‡ *Mining Journal*, vol. lxvi. p. 650.
§ *Engineering and Mining Journal*, vol. lxii. pp. 127–128.
‖ *Ibid.*, p. 52.
¶ *Journal of the Canadian Mining Institute*, vol. i. pp. 68–71, with map and sections.

City, and on the shores of Grand Lake, and covers an area of about 100 square miles. The most productive part is the Newcastle field, west of the river of that name. The dip seldom exceeds 4 or 5 degrees, and the surface conforms to the undulations of the strata. The only known seam of economic value is the "surface seam," which averages 2 feet in thickness, but varies from 1½ to 3 feet, and is often accompanied by a 6-inch seam. This coal-seam lies very near the surface, probably never deeper than 60 feet. Borings for deeper seams appear to have given unsatisfactory results. Assays of samples from three localities show :—

Volatile matter	37·30	35·25	37·10
Fixed carbon	59·35	55·80	61·10
Ash	3·35	4·20	1·80
Sulphur	2·66	1·68	1·98
Coke	62·72	60·00	62·90
Moisture	...	4·75	...

F. H. Mason and W. G. Matheson * give the assay results and the calorific value, as obtained by the Thompson calorimeter, for twelve samples of coal obtained from different localities in Nova Scotia. The colour of the ash, the character of the flame and of the coke are also given. The calorific values ranged from about 6800 to 7900.

E. Gilpin † mentions the fact that a collection of Nova Scotia minerals for the Imperial Institute contains several samples of coal.

Coal in South Africa.—Lapierre ‡ gives a short account of the Transvaal coal-deposits preliminary to a fuller account.

The geology of South Africa is described by Draper. §

Coalfields of Labuan.—A short description has been published of this island, off the coast of Borneo, and its coalfield.||

Coal in Alaska.—According to F. H. Curtis, ¶ coals of the Scotch splint and English cannel types are extensively found in Alaska. On Katchemak Bay there are about 2500 square miles of coal-lands, and a hundred seams are in sight within fifteen miles. One company has been

* *Journal of the Canadian Mining Institute*, vol. i. pp. 74–81.
† *Ibid.*, pp. 193–195.
‡ *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 383–408.
§ *Berg- und Hüttenmännische Zeitung*, 1896, p. 114.
|| *Indian Engineering*, vol. xix. pp. 242–243.
¶ *San Francisco Coll.*, through the *Engineering and Mining Journal*, vol. lxi. p. 474.

at work there for two years, employing fifty men, and work can be carried on throughout the year. About 40,000 tons of coal are consumed yearly in Alaska, and much of it is imported.

Coal in California.—According to H. W. Fairbanks,* coal of commercial importance is not met with in California below the Upper Cretaceous series, but the older coals have not yet been worked to any extent. The Lower Tertiary (Eocene) has furnished most of the coal mined at the present time, and the most important beds are found in the vicinity of Mount Diablo. The Miocene contains the most extensive series of coal-bearing rocks in this State, but the quality is poor, and there is some lignite in the north on the Pliocene horizon. A number of localities are mentioned in which coal has been found and worked. Nothing great is to be expected in this direction, but local demands might be better supplied, and exploration is necessary.

Coal in Idaho.—In the Sixteenth Annual Report of the United States Geological Survey, G. H. Eldridge gives an account of the coal found in Idaho.

Two coal-areas were encountered on the reconnaissance, one about Salmon City, the other at Horseshoe Bend on the Payette, twenty-eight miles north of Boise. Both areas are probably Tertiary—Eocene or Miocene—confirmatory plant-remains having been found in the beds at Salmon City, and the series on the Payette bearing a close general resemblance to these in composition, in manner of occurrence, and in folding. The coal occurs in small seams in sandstones, shale, or conglomerate lying within a few feet of the surface.

Coal in Pennsylvania.—Another valuable geological work is the summary description of the geology of Pennsylvania, issued in three volumes, covering 2638 pages, with 611 plates, by the State geologist. With a new geological map of the State, it forms a complete summary of the immense amount of detail contained in the long series of reports of the second survey of Pennsylvania. The coal measures are dealt with in the last volume, the bituminous coalfields being described by D'Invilliers.

Coal in Texas.—R. S. Weitzell † states that the bituminous coalfields of Texas extend from a point on Red River nearly north of Fort

* *Engineering and Mining Journal*, vol. lxii. p. 10.
† *Ibid.*, vol. lxi. pp. 473–474.

Worth, south-westerly across the State to the Colorado River. They are crossed by several lines of railway, but mines are only developed near three lines. The Texas and Pacific Coal Company's mines at Thurber are the oldest and largest. They have been worked since 1886. They now employ 1000 to 1500 men, and produce 1500 to 2000 tons daily. All the other mines are small. They work the coal in Stratum No. I. of the Texas series. It ranges from 20 to 30 inches in thickness, but averages 22 to 26 inches. It dips 60 to 80 feet to the mile to the north-west, whilst the surface rises in the same direction. The deepest shaft at present is 320 feet. The overburden chiefly consists of a light impervious soap-stone.

E. T. Dumble * states that the endeavours which have been made to utilise the brown-coal deposits in Texas are successful. It is now used on the railway.

Japanese Coal.—F. Browne † has examined a sample of the variety known as Tubari coal, from the island of Yezo. It was in large black lumps, which, when broken up, gave a dark chocolate-brown powder. It burned readily, giving at first a smoky flame, which disappeared after a short time, leaving a glowing mass. It is a non-caking coal. The results of the analysis show a high percentage of volatile combustible matter and of ash. It consisted of :—

	Per Cent.
Moisture	3·83
Volatile combustible matter	36·62
Fixed carbon	42·70
Ash	16·85
	100·00

Ultimate analysis of the dried coal gave :—

	Per Cent.
Carbon	62·84
Hydrogen	6·37
Nitrogen	1·08
Oxygen (calculated)	11·01
Sulphur (combustible)	1·18
Ash (containing 0·49 per cent. of sulphur)	17·52
	100·00

The relative density (water at $15·5° = 1$) was 1·411.

The heat of combustion calculated from the following formula :—

$$8080\ C + 34{,}462\ (H - 0/8) + 2210\ S \text{ gave 6826 calories.}$$

* *Engineering and Mining Journal*, vol. lxii. p. 343.

† *Chemical News*, vol. lxxiv. p. 76.

The Formation of Coal-Seams.—C. Ochsenius * discusses the origin of coal-seams. He does not believe that these had their origin in forests existing where the seams are met with, nor in peat-deposits; but considers that the only correct assumption is that they are the result of aqueous action washing the material into position. He points out that a quarter acre of the densest forest would only yield a coal-deposit 1·18 inch in thickness, and a forest cannot be carbonised at the bottom and yet keep on growing. Again, with regard to peat-beds, which, after all, are purely post-Tertiary, it is not possible to believe that these produced, say, fifty seams of coal, one above the other. The author thinks that there must rather have been a torrential forest stream pouring down into a lake, and forming sooner or later a dam of logs which kept back others subsequently, and allowed the clay, sand, and other smaller matter suspended in the water to flow over the dam. This matter settled at the bottom of the lake, and formed the shale with which coal is so associated. At higher water, branches, leaves, &c., would wash over the dam, circle about, become waterlogged, and fall in time to the bottom of the lake, while the smaller suspended matter would be carried farther away by the rushing waters. In times of high flood, boulders, sand, &c., would be washed down by the torrent, and these would cover over the logs behind the dam, and destroy the latter. This process would be repeated from time to time, and thus overlying coal-seams would have their origin. Under certain conditions, too, salt water might come into contact with these log dams, and it is easy to understand in this way all the points noticed in connection with seams of coal. The author next dealt with the connection of coal-seams with beds of ironstone, with differences in the bedding of brown-coal and coal, and other matters connected with this subject.

Discussing the occurrence of anthracite, W. S. Gresley † criticises Dr. Stevenson's theory of long exposure before covering, and leans towards that of the important influence of partial metamorphism.

H. Bolton ‡ discusses the conversion of bituminous coal into anthracite and graphite, and the conversion of carbonaceous matter into diamond.

The Classification of Coals.—For more than three years the subjoined table has been in use at the Trignac works. § It refers mainly

* *Chemiker Zeitung*, vol. xx. pp. 792–793.
† *Colliery Guardian*, vol. lxxii. pp. 273–276.
‡ *Ibid.*, vol. xvi. pp. 254–255.
§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 228.

to British coals, and shows their relative coke-forming capacity as measured by the Campredon method. In this latter the coal is powdered to such a size that it will pass through a sieve of 100 meshes to the square centimetre, but not through one of 400 meshes. It is then mixed with quartz sand, and heated to bright redness in small porcelain crucibles. The character of the coke is then ascertained, and that coal which, while giving a satisfactory coke, will stand admixture with the largest quantity of sand is the best coal, and the quantity of sand represents the value of the coal. Thus, for 1 gramme of coal, the highest value attained was 17 of sand, and for 1 gramme of tar, 20 of sand. In the following table this capacity is shown under the heading V. The coals were dried at 100° C.

Assay Results.

Volatile Matter.	Ash.	Fixed Carbon.	V.
10·90	6·20	82·90	0
34·25	10·80	54·95	2
34·72	8·35	56·93	4
27·20	8·70	64·10	13
28·12	8·55	63·33	0
19·80	7.70	72·50	6
27·83	8·75	63·42	14
29·50	8·50	62·00	17
44·82	0·60	54·58	20

The extreme difference shown between the fourth and fifth samples is of much interest, bearing as it does upon the molecular constitution of the coal, affecting so enormously its coking properties.

B. Halberstadt * discusses the classification of bituminous coals, showing what constitutes good steam, gas, smithing, and coking coals.

III.—*CHARCOAL.*

Charcoal-Making in the United States.—The charcoal made at the Hinkle Furnace, near Ashland, Wisconsin, is stated by E. G. Odelstjerna † to be made in ovens which are in part provided with an arrangement for the collection of the by-products. Other ovens used are not so provided. These latter are usually 24 feet in width at

* *Colliery Engineer*, vol. xvi. pp. 257-258.
† *Jernkontorets Annaler*, vol. l. pp. 169-404.

the bottom, and 22 at the top, and 12 feet high, being covered in with a $5\frac{1}{2}$-foot domed roof. The brickwork is 317 millimetres thick, and they are banded with two or three iron bands. The oven is either lit from the dome, or else below. The wood is charged in at the side through an opening, which is subsequently walled up. The yield is about 84 per cent. by volume.

The ovens arranged for the collection of the by-products are 16 feet wide at the bottom, and 14 at the top, the height being about the same as that of the ordinary ovens. There are twenty-two such ovens erected. At one side of the furnace, beneath the bed, is a fire, the waste gases from which pass under the bed of the furnace, and then up through an orifice in the centre of this into the interior of the oven. On the other side of the oven, near the bed, opposite the firing, is an orifice connected to a pipe leading to the refinery. Through this the by-products distil; 1200 cubic feet of wood are stated to yield 1000 cubic feet of charcoal and 128 gallons of methyl alcohol. Each of these two kinds of oven is provided with two or three rows of air-holes.

IV.—*COKE.*

The Manufacture of Coke in Pennsylvania.—W. T. Rainey * briefly describes the manufacture of coke and its selection for the foundry, with especial reference to the Connellsville district. The coal there is very bituminous, and practically is only used for coking. The coke is quenched in the oven, and is burnt for 48 or 72 hours. For the longer period the charge of the oven is increased, and this is done at the week end, and also when the ovens are laid off for a day. The author states that he is unable to distinguish between 48 and 72 hours coke. Some uncoked coal is left at the bottom of the charge, otherwise the coke will run high in ash. All the coke as it comes from the oven is used for furnace work; but for foundry purposes the coke is picked, and more carefully packed in box cars, so as to leave larger pieces showing through the slits in the door.

The Coke Industry.—J. Fulton * discusses the vast importance of the coke industry, showing the value of coke for metallurgical and

* Paper read before the Foundrymen's Association, through the *Iron Age*, vol. lvii. p. 1354.

† *Engineering Magazine*, vol. xi. pp. 208–231.

domestic purposes, and describing the various types of coke ovens, with their advantages and disadvantages. His memoir is illustrated by drawings and photographs of the modern types of coke oven, and contains statistics of the manufacture of coke in the United States from 1880 to 1894. The essential elements in the physical and chemical properties of good metallurgical coke are—(1) Hardness of body, (2) fully developed cell structure, (3) purity, and (4) uniform quality. The following table shows the work of the three chief fuels in blast-furnace practice:—

		Charcoal.	Anthracite.	Coke.
Analysis:—				
Moisture		3·50	2·50	0·49
Volatile matter		6·40	4·00	0·01
Fixed carbon		87·00	87·00	87·46
Ash		3·00	6·00	11·32
Sulphur		trace	0·50	0·69
Size of furnace	feet	12 by 60	17 by 65	22 by 90
Per cent. iron in ore		55	55	59
Lbs. of fuel to 1 ton pig		1,815	2,244	1,737
Output per month	tons	3,379	2,698	10,536
Relative values:—				
Economy		100	123	96
Speed		100	80	311
Purity		100	97	94

The furnaces whose working is thus recorded are situated in Wisconsin, in New Jersey, and at the Edgar Thomson Works, Pennsylvania.

Coke Works in the Connellsville Region.—An interesting description of a modern mine and coke works in the Connellsville region, has been published* by H. L. Auchmuty. The colliery described is the Leith mine, and full details are given of the geological features of the deposit worked, of the system of mining employed, and of the methods of timbering, ventilation, and draining, as well as of the surface improvements. One of the most interesting structures is the Bessemer steel pithead frame, which is secured to a foundation of sandstone masonry, resting upon solid rock 22 feet below the surface of the ground. The bottom dimensions of the masonry outside the interior shaft timbering are 28 feet 6 inches, by 48 feet 10 inches, with a width of 8 feet 1 inch. The total height of the pit-frame is 85 feet. The legs are formed of four Z-bars riveted to a central web. Closely connected to the pit-frame is the coal-bin, with a

* *Colliery Engineer*, vol. xvii. pp. 1–7.

capacity of 480 tons of coal. The total amount of steel used in the pit-frame and the coal-bin was 207,916 lbs. The 306 coke ovens at this mine are arranged in two long double blocks, parallel to each other. The ovens are all 12 feet in diameter, and of the ordinary beehive type. The coal for supplying the ovens is conveyed from the bin in iron trucks holding 190 bushels each.

A Mechanical Coke Drawer. — R. A. Cook * describes the machine devised by T. Smith for drawing the coke from beehive ovens. About thirty of these machines are now in use, and the author gives illustrations of two of them used at Latrobe, Pennsylvania, where there are thirty ovens. The appliance consists of a wedge-shaped shovel carried by a rack sufficiently long to reach the back of the oven. The rack is guided to reach all parts of the oven except the parts just at the sides of the doors. It is driven by a single cylinder engine with reversing gear. Both engine and machine are mounted on a truck running on rails in front of the oven. A nine horse-power boiler on a separate truck supplies power. The shovel is thrust under the coke, and, being wedge-shaped, the coke drops over the thicker end, and is drawn out when the rack is retracted. Belt conveyors between the machine and the ovens remove the coke to a screen.

Coke-Oven Gases.—A proposal has been made to establish, in the State of Massachusetts, a central undertaking, which, by means of pipe lines, will distribute the gases evolved from a very large coke-oven plant. In connection with this proposal J. D. Weeks † and F. L. Slocum have investigated the question, and a number of analyses have been published.

The following are assay results of Pennsylvania coal and coke :—

	Anthracite.	Bituminous. Coal.	Coking Coal.	Coke.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	83·672	60·92	73·728	92·550
Volatile matter and moisture .	5·582	32·60	21·970	1·104
Ash	10·746	6·48	4.672	6·346
Totals . .	100·000	100·00	100·370	100·000

* *Transactions of the American Institute of Mining Engineers;* Pittsburgh Meeting (advance proof).

† *American Manufacturer,* March 20, 1896; *Stahl und Eisen,* vol. xvi. p. 519.

In addition, the analyses of various illuminating gases are given, and also the gases from the Hüssener, Otto-Hoffmann, and Solvay ovens. These contained :—

	Per Cent.
Carbon monoxide	4·46 to 8·80
Oxygen	0·00 „ 0·44
Hydrogen	52·77 „ 61·40
Methane	23·70 „ 36·11
$C_2H_4+C_6H_6$	2·03 „ 3·10
Carbon dioxide	0·88 „ 3·27
Nitrogen	0·00 „ 5·74
Hydrogen sulphide	0·00 „ 0·43

The total percentage of combustible constituents, that is, was about as high as in ordinary illuminating gas, or nearly so.

Villot * gives a few particulars of the use of waste gases from eighty-four Coppée coke ovens at the Sainte Barbe collieries, Carmaux. A Belleville boiler was constructed in 1894, and gave such excellent results that a large electric plant is to be installed, and it is expected from the results obtained that 900 to 1000 horse-power may be utilised.

The Saving of By-Products.—R. A. Cook † gives an illustrated description of a plant used at Sheffield, for saving the by-products from beehive ovens, and also of a modification of the system which has been in use at Latrobe, in Pennsylvania. At Sheffield there are 100 ovens 11 feet in diameter and 8½ feet in height. They are carefully built so as to be air-tight. A fire-clay pipe built into the crown of the oven connects with an iron main, and supplies heated air for combustion. An opening in the floor communicates with a cast-iron main in which heavier liquids are separated. The gas passes through a surface condenser consisting of vertical cast-iron pipes, and is then burnt under eight large Lancashire boilers, thereby saving 1000 tons of coal weekly. The tars and other products are treated in a still. Nine gallons of crude oil and 5½ lbs. of ammonium sulphate are recovered from each ton of coal. In the experimental plant at Latrobe, thirty ovens have been erected, and the addition of a small scrubber, to remove more ammonia, has been made.

The collection of ammonia during the coking process is discussed editorially in *Stahl und Eisen*.‡ The ammonia that results in this way

* *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, pp. 45-46.

† *Transactions of the American Institute of Mining Engineers;* Pittsburgh Meeting (advance proof).

‡ Vol. xvi. pp. 313–315.

has its origin in the nitrogen that is present in the coal treated, but knowledge of the chemistry of the subject is a matter of recent progress. It was formerly thought that well-burnt coke could not contain nitrogen; yet it contains large quantities, as can be shown by treating it with steam. To completely eliminate the nitrogen, blast-furnace temperature is necessary. Coke taken from the tuyere level is stated to have been free from nitrogen. Another point, which was the subject of erroneous opinions, was connected with the total percentage of nitrogen in the coal. It was thought that the higher the total percentage of nitrogen the higher would be the quantity of ammonia that could be obtained, but it is quite erroneous to make any such deductions. Foster has shown in the case of coals from the United Kingdom, that from 48 to 65 per cent. of the nitrogen remains in the coke, from 21 to 35 per cent. passing away with the gases, and from 0·2 to 1·5 per cent. forming cyanogen, while only 11 to 17 per cent. was converted into ammonia. Earlier experiment by Knublauch showed that in the case of Rhenish-Westphalian coals from 31 to 36 per cent. of the original nitrogen remained in the coke, 1·5 to 2 per cent. passing away as cyanogen in the gas, 1 to 3 per cent. remaining in the tar, while from 10 to 14 per cent. was converted into ammonia. This latter author has since made a detailed examination into this question.* He shows that the percentage of original nitrogen which is available for the conversion into ammonia is very small. Of a total original percentage of nitrogen in the coal of about 1·5 per cent., only about one-seventh (from 0·2 to 0·25 per cent.) was available for ammonia. He shows that it is impossible to draw any conclusion as to the yield of ammonia from the percentage of nitrogen contained in the coal. Indeed, that coal which, in his experiments, contained the highest percentage of nitrogen (1·555) was the one that yielded the lowest percentage of ammonia. In the course of these experiments the author devised a distillation process for the coals examined, and submitted a large number to such tests. Sixty-six results are given, of which a summary is given on the next page. It will be observed that the quantity of ammonium sulphate obtained per ton of coal treated varied from as little as 4 lbs. to fifteen times that amount. The variations in the yield of this by-product are thus extremely wide, and similar wide variations are noticeable in connection with the production of tar.

* *Journal für Gasbeleuchtung und Wasserversorgung*, 1895.

Coal.	Cubic Metres of Gas per Metric Ton of Coal.	Coke.	Tar.	Ammonia.	Average Sulphate per Metric Ton.
		Per Cent.	Per Cent.	Per Cent.	Kg.
Westphalian gas coal	254·0 to 303·0	69·15 to 74·80	3·60 to 5·00	0·2411 to 0·2649	10·4
Westphalian cannel coal . . .	314·9 ,, 339·2	51·65 ,, 62·55	5·90 ,, 10·20	0·1799 ,, 0·1919	7·7
Westphalian coking coal . . .	261·0 ,, 293·0	74·80 ,, 84·80	1·30 ,, 3·40	0·2330 ,, 0·3059	11·0
Upper Silesian gas coal . . .	282·0 ,, 308·0	63·45 ,, 68·20	1·86 ,, 4·90	0·2800 ,, 0·4049	13·5
Lower Silesian gas coal	301·0 ,, 302·6	70·50 ,, 71·25	4·30 ,, 4·90	0·1785 ,, 0·1945	7·7
Lower Silesian coking coal . . .	253·0 ,, 286·8	71·15 ,, 80·55	2·10 ,, 3·40	0·1969 ,, 0·2084	8·4
Saar gas coal . .	280·8	64·75	5·10	0·2275	9·4
Saar coking coal .	266·8 ,, 302·2	67·75 ,, 70·10	3·30 ,, 3·70	0·1831 ,, 0·1975	8·2
English gas coal .	303·0 ,, 327·2	59·75 ,, 69·50	3·81 ,, 5·90	0·2720 ,, 0·4661	16·4
Belgian coal . .	261·5	70·75	4·60	0·1646	6·8
Moravian coking coal	262·9 ,, 288·6	78·44 ,, 85·45	1·60 ,, 3·20	0·2017 ,, 0·3151	10·6
Russian coal . .	263·2	62·65	6·50	0·2875	11·8
North American coal	270·6 ,, 317·4	52·83 ,, 84·82	1·70 ,, 5·80	0·1741 ,, 0·2880	9·4
South American coal	302·8	61·25	4·50	0·3240	13·3
Italian coal, lignitic	310·3 ,, 341·6	53·35 ,, 56·95	2·60 ,, 3·00	0·6661 ,, 0·7242	28·9
Bohemian Platten coal . . .	328·0	54·80	8·40	0·2193	9·0
Bohemian brown coal . . .	463·0	34·85	10·90	0·1384	7·4
Scottish cannel coal	334·0 ,, 345·0	46·45 ,, 48·05	7·30 ,, 10·50	0·1447 ,, 0·2382	7·9
Spanish coal . .	236·0	37·25	10·80	0·0544	2·3
Australian coal .	371·0 ,, 416·0	25·75 ,, 42·20	9·90 ,, 17·80	0·0463 ,, 0·0475	1·9

The conclusions that Knublauch draws from these investigations are, that in coals of the same seam, great differences occur as regards the yield of ammonia obtainable from them; that in coals from different seams, this difference is a very wide one; and that in the case of gas and coking coals from the same field, the coking coal will show a higher yield of ammonia than will the gas coal. This last conclusion, it is observed, is open to question in some respects.

In another editorial article* it is pointed out that during the past two years there has been built a very large number of coke ovens, arranged for the collection of the by-products. In 1894 there was an increase in the production of coke in the Ruhr district, amounting to 12·93 per cent. over the output of the previous year, and in 1895 a further increase of 3 per cent. The cost of production showed, in the case of the Hibernia Company, a diminution amounting to 13·93 per cent. when the cost in 1894 was compared with that of 1893; but the variations in cost have been irregular at various works. In 1886 the

* *Stahl und Eisen*, vol. xvi. pp. 667-670.

average cost of coking per ton of coke amounted to 1s. 4¼d., each oven making on the average 2·73 tons in twenty-four hours. Round ovens have been abandoned in this district since then, and the average cost has been brought down in 1895 to about 1s. 1d. Various works, however, fall considerably below this; while, on the other hand, the cost is considerably higher at others. The following are some costs quoted in connection with the cost per ton of coke made in ovens on different systems; but, as the ovens are working at different works and under different conditions, the costs are not strictly comparable:—

	Otto Ovens.	Solvay Ovens.	Bernard Ovens.
	Shillings.	Shillings.	Francs.
Cost of coal	11·48	11·31	11·28
Wages	0·60	0·66	0·46
Supervision and general charges	0·06	0·06	0·11
Depreciation	0·30	0·30	0·25
Materials	0·01	0·09	0·25
Totals	12·45	12·42	12·35

The cost of coking was thus 0·97, 1·11, and 0·86 shilling in the cases mentioned. The Bernard ovens quoted are at work in the Belgian coal-field. At a battery of fifty Coppée ovens in Belgium it is stated that the cost of manufacture of the ton of coke is 1s. 2d. Comparing the costs in Belgium and in the adjacent Ruhr district of Germany, it is shown that the wages per ton in Belgium are only about 4¾d., as compared with 7d. to 8d. in the German coalfield. Taking everything into consideration, and assuming that the first cost of an oven is £200, and that the average out-turn is 1000 tons of coke, the following estimate is drawn up of what the cost per ton of coke should be under normal conditions:—

	Shilling.
Wages and supervision	0·640
Materials	0·100
Repairs	0·050
Insurance, sick fund, and taxes	0·025
General charges	0·005
Interest and depreciation	0·200
Total	1·020

The use of better charging and discharging methods is recommended, and a traveller for this purpose is illustrated. The advantage of the use of a wire ropeway for carrying the coke to the throat of the blast-furnace

is also referred to, and various other suggested modifications, with a view to save labour, are briefly mentioned.

It is stated * that 120 Otto-Hoffmann ovens with by-product recovery plant are being built by the Pittsburgh Gas and Coke Company, at Glassport, about twelve miles from Pittsburgh.

G. Hilgenstock † describes the recent coke ovens arranged for the collection of by-products, referring specially to the ovens of Otto-Hoffmann, Collin, Ruppert, and Brunck.

An historical account has been published of coke-making, with a study of the economical problems connected with the industry.‡ Illustrations are given of Otto-Hoffmann and Semet-Solvay coke-oven plants.

R. M. Atwater § discusses coke oven construction, showing its effect on the coke, referring especially to the Semet-Solvay oven. The object of the paper is to describe methods of coking with Pittsburgh coal.

J. S. Kennedy ‖ discusses the results and the value of by-products obtained on retort coking. He also discusses the different systems employed.

In an exhaustive article on by-product coke ovens, W. H. Blauvelt ¶ describes the by-product oven in Europe and America, reference being made to the ovens of Pauwels, Knab, Carvès, Aitken, Jameson, Shrewsberry, Newton-Chambers, Coppée, Otto-Hofmann, Simon-Carvès, Huessener, Semet-Solvay, Festner-Hofmann, Siebel, Barnard, and Slocum. He concludes with a comparative table of coke oven costs.

Coke Oven for Brown Coal.—An illustration is published ** showing some of the details of a coke oven used at the Anhalt collieries in the coking of brown coal. This coal is first dried in a drying-chamber forming part of the oven. The arrangement of the oven is patented, and various advantages are claimed for it.

The production of this substance in the Saxon-Thuringian district in 1895 did not differ much from that in 1894. The total production was 62,500 tons. The quantities of the different products obtained in its distillation are also given. It is in nearly every instance distilled with the addition of only lime or caustic soda, without prior chemical treatment, and the products are then submitted to the so-called mixed process.††

* *American Manufacturer*, vol. lix. p. 44.
† *Glückauf*, vol. xxxii. pp. 497–502.
‡ *Engineer*, vol. lxxxii. pp. 205–206, 303–306, with twenty-three illustrations.
§ *Colliery Engineer*, vol. xvi. p. 258.
‖ *Tradesman*, August 15, 1896.
¶ *The Mineral Industry*, vol. iv. pp. 215–242.
** *Osterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 491.
†† *Chemiker Zeitung*, vol. xx. pp. 373–375, with one illustration.

V.—*LIQUID FUEL.*

The Origin of Petroleum.—C. Ochsenius,* considering the origin of petroleum, concludes by observing that he first propounded the theory that petroleum originates mainly from the bodies of marine organisms which were first killed in part by salt solutions, and then remained under treatment by these under exclusion of air; that Engler did not obtain petroleum by his pressure treatment, but that Heusler produced petroleum synthetically from Engler's product by the use of aluminium chloride, thus bearing out the author's theory.

The Flashing-Point of Petroleum.—C. A. Lobry de Bruyn † replies to various objections which have been raised to his opinions on this matter, ‡ and gives further details.

The same subject is dealt with by M. Dennstedt, § who gives a table showing in the case of twelve oils the flashing-point, their specific gravity, the temperature at which boiling begins, the quantities distilling off at different temperatures, and the solidifying-point. The following is a summary:—

	Flashing Point. Degrees of Scale.	Specific Gravity.	Distillate. Up to 150° C.	150° C. to 270° C.	Over 270° C.
Minimum	21·00	0·793	19·2	43·10	23·9
Average	22·35	0·796	22·7	46·76	29·0
Maximum	24·50	0·800	25·8	55·60	35·1

R. Kissling ‖ replies to Lobry de Bruyn's paper and reply above mentioned. He is of opinion that raising the flashing-point must also raise the market price of the oil, and doubts the necessity for any action. The same subject is also dealt with by S. Aisinman, ¶ making Lobry

* *Chemiker Zeitung*, vol. xx. pp. 383–384; *Zeitschrift für praktische Geologie*, 1896, p. 921.

† *Ibid.*, vol. xx. pp. 623–627.

‡ *Journal of the Iron and Steel Institute*, 1896, No. I. p. 353.

§ *Chemiker Zeitung*, vol. xx. pp. 637–640.

‖ *Ibid.*, vol. xx. pp. 358 and 648.

¶ *Ibid.*, vol. xx. pp. 396–397.

de Bruyn's paper his basis for consideration, favourably criticising it, and giving additional information. Lobry de Bruyn's suggestions have led to much general discussion.*

The new legal requirements in connection with the testing of petroleum and petroleum products in Russia are also published; † and the technical utilisation of petroleum and its products is described by S. P. Sadtler. ‡

Oil Industry of Baku.—W. F. Hume § gives an interesting account of the rapid growth of the town of Baku, due to its excellent harbour and the oil supply. He traces the history of the growth of the naphtha industry, and gives descriptions of wells and methods of working, with other useful information.

Petroleum in California.—According to H. W. Fairbanks, ‖ there has been no systematic examination of the oil-bearing strata in California where it occurs in the Miocene formation, in clays, shales, limestones, and banded flints. The oil-bearing shales extend from a little south of Los Angeles as far north as San Francisco, a distance of nearly 400 miles, but erosion has removed them to a considerable extent. The most southerly field developed is Los Angeles, north-west of which is the field about Newhall and the Santa Clara Valley, where oil was first found. From this point the shales extend continuously northwards along the coast, through Santa Barbara and San Luis Obispo counties. Other counties in which the oil shales occur are also mentioned.

Petroleum in Ohio.—F. C. Thiele ¶ discusses the so-called "Lima" petroleum, which is found in the neighbourhood of Marietta and Lima, in Western Ohio. It differs considerably from the Pennsylvania oil. The latter is much lighter in colour, and yields up to 70 per cent. of illuminating oil; while the Lima oil rarely yields more than 32 per cent., and contains up to 0·5 per cent. of sulphur. The author deals with the elimination of this sulphur and its determination analytically.

R. Kissling ** publishes the results of fractional distillation of various petroleums, giving details as to the quantities of the various products

* *Chemiker Zeitung*, vol. xx. pp. 359–360.
† *Ibid.*, vol. xx. pp. 357–358.
‡ *The Mineral Industry*, vol. iv. pp. 503–512.
§ *Nature*, vol. liv. pp. 232–234.
‖ *Engineering and Mining Journal*, vol. lxi. p. 588.
¶ *Chemiker Zeitung*, vol. xx. pp. 515–516.
** *Ibid.*, vol. xx. pp. 369–371.

obtained. In tabular form he gives such details for seven European oils, seven from the United States, one from Canada, four from Asia, and one from Australia. Of these, the one with the highest specific gravity, 0·922, was from Japan; one from Oelheim, in Hanover, running this close—0·909. The lightest oil had the specific gravity 0·791, its origin being Pennsylvania. The fractional distillates were those up to 100°, between 100° and 130°, 130° and 160°, 160° and 200°, 200° and 250°, 250° and 300°, 300° and 320°, and above this. For each of these, the quantity obtained, its specific gravity, and its colour are given.

The Wyoming Oil-Fields.—W. C. Knight * describes the oil-fields of Wyoming which were discovered about half a century ago, but were not much worked until 1894. Probably the output in 1896 will be 50,000 barrels. There are eighteen known oil-basins in Wyoming, of which twelve are in the central portion, two in the north-east, and four in the south-west; and a large amount of land has already been secured. The geology of the district is as yet imperfectly known, but the oil is found to occur chiefly in Mesozoic rocks, though it is also found in Paleozoic and Cenozoic formations. The wells already bored vary from 300 to 1500 feet in depth. The oils are principally lubricating; but some light oils are found, and their specific gravities range from 0·8544 up to as much as 0·9950. At present, transportation facilities are deficient, but the production will advance as these are increased.

The Petroleum Industry in Japan.—An article† has been published showing the value of the oil industry in Japan, and discussing its effects on the markets of China and India.

Oil-Fired Furnaces at Cleveland.—In the course of a visit to the United States, E. G. Odelstjerna ‡ visited the works of the Cleveland Hardware Company. All the furnaces at this works are heated by oil which is pumped from a small open reservoir into a closed one at a higher level. In this it is at a pressure of 12 lbs. to the square inch. When this pressure is exceeded, a safety-valve opens and allows the oil to flow back into the open tank until the pressure is again normal. From the high-pressure reservoir, pipes pass in all directions to the various furnaces belonging to the works, into which the oil passes through

* *American Manufacturer*, vol. lviii. pp. 763–764.
† *Indian Engineering*, vol. xix. p. 370.
‡ *Jernkontorets Annaler*, vol. l. pp. 169–404.

smaller pipes provided with cocks, by the opening and shutting of which the temperature of the furnace can be regulated. The stream of oil as it enters the furnace strikes against a firebrick and splashes into a fine spray, which rapidly lights.

VI.—*NATURAL GAS.*

Natural Gas in the United States.—E. G. Odelstjerna * states that the gas obtained from sandstone beds is marked by its high percentage of paraffins, amounting in two cases mentioned to 84·26 per cent. and 97·70 per cent. respectively. The gas from limestone beds, on the other hand, contains a large percentage of marsh gas and low nitrogen; the percentage of these two gases being respectively in cases mentioned, 92·84 and 3·82, and 93·85 and 2·98.

In different gas-fields the gas pressure varies greatly, but it is the same for any particular field. The highest yet observed was 796 lbs. per square inch, the average pressure when first struck being from 398 to 497 lbs. per square inch. How quickly this gas pressure sinks is seen from the following example:—

Date.	Pressure. Lbs. per Square Inch.
February 13, 1886	462·2
April 27, 1889	391·1
December 16, 1889	248·9
May 26, 1890	177·7
November 3, 1890	99·5
December 1, 1890	95·2
February 2, 1891	65·4

Four wells in the Findlay field yield the following quantities of gas a day:—

Well.	Output. Cubic Feet.
Karg	12,080,000
Cory	3,318,000
Briggs	2,565,000
Jones	1,159,200

The author generally reviews the subject, and refers to it historically. An attempt was first made in Fredonia, in 1821, to practically apply natural gas for lighting purposes, but the existence of the gas was

* *Jernkontorets Annaler*, vol. l. pp. 169–404.

previously known. In 1874 natural gas was experimented with at a blast-furnace near Erie, but no saving of fuel was observable, and the experiments proved unsuccessful.

From a report by J. D. Weeks * on the production of natural gas, it appears that among the notable features in connection with the production of natural gas in America in 1895 may be mentioned:—

1. The decreasing pressure in all the natural gas-fields of the country. As is seen by reference to the statements under the reports by States, the rate of decrease in pressure varies greatly in the several States, owing to local reasons. In Pennsylvania, for example, this decrease seems to be the greatest, owing to the fact that the gas-fields of this State are the oldest, and have been the most heavily drawn upon. In Ohio it is the least, the great decline in pressure in this State having taken place some two or three years ago. The shallow-well, low-pressure fields of this State maintain both pressure and production quite uniformly, and, though there is some decline in pressure even in this field, the ratio is small. The decline in pressure in the wells in Indiana is midway between the declines in these two States; but if the statement made by the natural-gas inspector of Indiana is true, that when the pressure declines to 200 pounds the wells are usually drowned out by water, the Indiana gas producer will have to contend with a more serious condition of affairs than either the Ohio or Pennsylvania producer.

2. Resulting from the same cause that leads to this decline in pressure, viz., the reduction in the supply of gas stored in the earth's reservoirs, there is a great falling-off in the production of gas per well. The only way in which the production can be maintained, in view of the reduction of supply and decrease in pressure, is to drill more wells. This is resorted to, where possible, in order that the supply may be maintained.

3. As a further result of the decline in pressure and reduction in supply, the life of the wells, or the time during which a well in a given locality will produce gas in commercial quantities, has been very much reduced. How great this reduction has been in some cases is evident on an inspection of the reports from the various States. In some cases in Western Pennsylvania the average life of a well in a field is but six months; in others, two or three years, though in the latter case with continually decreasing pressure and production.

It appears that the value of natural gas consumed in the United States was greatest in 1888, when the value was 22,629,875 dollars.

* *United States Geological Survey. Sixteenth Annual Report,* part iv. pp. 405–429.

From that time to 1891 the decrease in value was rapid. Since 1891, however, it has been very gradual, owing to the fact noted that meters are being used, the amounts consumed measured, and payments made on amounts used.

VII.—*ARTIFICIAL GAS.*

A Feed for Gas-Producers.—C. W. Bildt * describes, with illustrations, a feed for gas-producers, designed by himself, and successfully used at some Swedish works at Trollhatten, and at Worcester, in Massachusetts. This feed is also used for other furnaces burning small or dust coal. The top of the producer is surmounted by a hopper, which is filled with coal, and kept closed to prevent escape of gas. Underneath the open end of the hopper is a rotating disc with spiral blades on its upper surface. These blades are so formed that coal is distributed uniformly all round the periphery as the disc revolves.

Illustrations are published † of a coal storage plant built at South Chicago for supplying twelve gas-producers. It consists of a long bin holding five days' supply, supported on iron columns over the producers. Shoots at the bottom of this bin are placed directly over the producer feeding-holes. On the top of the bin travels an electric crane to lift coal from the railway trucks which run alongside of the producers.

New Gas-Producers.—The producer designed by A. Kitson, of Philadelphia, has an inclined rotating bottom and an automatic feed. Illustrations recently published ‡ show the body of the producer supported on six 10-inch girders carried on walls 4 feet in height. The hearth consists of a steel plate running on ball bearings, and having its upper surface inclined at about 25 degrees from one side. It is given rotation in alternate directions at the rate of about one revolution in thirty minutes, so as to break up the clinker. The ash falls out at the periphery, and its removal is aided by adjustable scrapers which direct it into a water seal. The air and steam blast is central. A belt-shifting gear controls the alternate revolution, and the feed is driven by a cam on the main shaft.

In the Gardie producer,§ air under high pressure is used, and the

* *Jernkontorets Annaler*, vol. l. pp. 150–162.
† *Iron Trade Review*, vol. xxix. No. 34, pp. 12–14.
‡ *Iron Age*, vol. lvii. pp. 1022-1024.
§ *Ibid.*, p. 1072.

producer is entirely closed. Steam is superheated in a coil at the top, and is introduced with the air, which is supplied at 42 lbs. per square inch. Coal is introduced through a hopper and valve. An analysis of the gas is given as follows:—

H.	CO.	C_2H_4.	C_4H_4.	N.	O.	CO_2.	Total.
15·0	24·0	3·5	0·5	51·5	0·5	3·0	98 *

VIII.—*COAL-MINING.*

Shaft-Sinking.—A. Gobert † describes his modification of Poetsch's method of sinking shafts by the freezing process, in which liquefied ammonia is introduced into the freezing pipes by a serpentine perforated tube. With this process the pressure in the tubes is less than the external pressure, and any leakage that may occur is into the tube, and is speedily stopped when the ice forms. In the ordinary process a leakage of solution delays or prevents formation of ice. By regulating the admission of the liquefied ammonia it may be caused to evaporate completely before it falls far down the tube, so that the upper strata may be frozen first; or by increasing the supply the shaft can be frozen throughout in the first instance. If too much ammonia is introduced, it collects at the bottom of the tube and evaporates more slowly. An excess is shown by the lowering of temperature at the compressor. Illustrations of the plant are given.

H. F. Olds ‡ describes in detail the sinking of two shafts by the Poetsch freezing process by the Anzin Mining Company at Onnaing, near Valenciennes, France.

A brief account § is given of a method employed in sinking a shaft through a bed of some 36 feet of quicksand, to open up a large seam of brown coal. After various methods had been tried without effect sinking-pit masonry was used with success. This method has been adopted at many Upper Silesian pits.

Prud'homme ‖ describes the method adopted for enlarging the section, and for renewing the tubbing of a ventilating shaft (St. Mark No. 1 pit) at the Anzin collieries. Details are given of the cost of the operations.

* The total in the original is given as 100·0.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 297–305, with one plate.

‡ *Transactions of the Institution of Mining and Metallurgy*, vol. iv. pp. 241–247.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 407.

‖ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, pp. 48–57.

Gardon * describes in detail the sinking and lining of the Conte-Grandchamps shaft, 300 yards deep, of the La Chapelle-sous-Dun collieries.

Lücke † describes the shaft-boring operations in aqueous strata at the Rheinpreussen colliery, near Homberg on the Rhine.

Wire Ropes.—In the Breslau district 1497 wire ropes have been renewed in the fourteen years 1882–1895.‡ Of these there broke suddenly 18 round crucible steel ropes, 11 round iron ropes, and 9 flat crucible steel ropes, or, respectively, 1·45, 9·40, and 6·67 per cent. of those renewed. In 1882 the percentage of ropes that fractured suddenly was 9·62, while in 1895 it was only 3·65. This reduction is mainly due to the fact that not only the iron ropes, but also the flat steel ropes, are now less frequently used than was formerly the case. The ropes that broke in 1895 broke mostly at those parts where the rope was chiefly exposed to the bending strain. A comparison between the work done by a flat wire rope during its lifetime as compared with that of a round wire rope is very greatly in favour of the latter—the round rope lifting 230,012 millions of kilogramme-metres, as compared with 28,368 millions in the case of the best flat rope.

O. Hoppe § refers to the work done by Albert in the years 1806–1834, now almost forgotten. This referred largely to wire ropes, and also to some of the physical changes in iron met with in practice.

J. Bucknall-Smith || discusses the technology, manufacture, and uses of wire mining ropes.

In response to a suggestion by Westgarth that details of the horizontal and vertical angles at which winding ropes are worked at various pits, of the sizes of ropes, nett working load, daily output, life of the rope, dimensions of pulleys and drums, should be collected, several papers on this subject have recently appeared. H. F. Bulman ¶ gives the particulars for a shaft 483 feet deep. Two-decked cages, weighing when loaded $45\frac{3}{4}$ cwts., are used. The rope is $3\frac{1}{8}$ inch in circumference, weighing 11 lbs. per fathom. The pulleys are 11 feet, and the drum 17 feet in diameter. The angles made by the two ropes are 76° and 62° with the horizontal, and the ropes last two years on the average.

* *Bulletin de la Société de l'Industrie Minérale*, 1896, p. 83, with six plates.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. xliv. pp. 156–162, with one plate.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 468.

§ *Stahl und Eisen*, vol. xvi. pp. 437–441, and 496–500.

|| *Mining Journal*, vol. lxvi. pp. 714, 746, 782, 814.

¶ *Journal of the British Society of Mining Students*, vol. xviii. pp. 83–85.

G. W. Westgarth* gives an instance where round ropes replaced flat ropes with great advantage. Formerly flat ropes, about 680 yards long and $4\frac{7}{8}$ inches by $\frac{7}{8}$ inch, were used at a cost of 0·55d. to 0·60d. per yard per ton, and would only last eight or nine months. The drums and pulleys were then enlarged, and round ropes $5\frac{1}{4}$ inches in diameter, of best plough-steel, were employed. The lower rope raised altogether 247,000 tons of coal, besides 200 to 300 tons of rubbish daily, at a cost of 0·119 penny per yard per ton. The saving thus amounted to 0·48 penny, or a total of £494. For the sake of comparison, the author advocates the estimation of cost on the basis of the ton of coal raised, divided by the length of the rope, so as to give the cost per ton per yard.

G. E. F. M'Murtrie† and C. F. Scott‡ also deal with ropes. The former mentions the oiling of winding ropes, and the strains during winding when the rope is slack at the start, and the latter giving calculations as to friction on hauling ropes.

A. A. Atkinson § gives a sketch of the arrangement of winding ropes at the Barrow Collieries. These are $1\frac{1}{2}$ inch in diameter, the drum and pulleys are 20 and 18 feet in diameter, and the load 153 and 158 cwt. at the two shafts, 410 and 480 yards deep respectively. The costs per ton drawn ranged from 0·296d. down to 0·062d. per ton:—

	Length.	Days Worked.	Tons Drawn.	Cost per Ton.
	Yards.			Penny.
Over rope, ...	540	549	188,185	0·096
,, ...	540	960	210,144	0·095
Under rope, ...	540	979	211,596	0·114
,, ...	540	293	70,715	0·296
Over rope, ...	600	608	154,004	0·169
,, ...	600	864	139,256	0·170
Under rope, ...	620	1218	339,128	0·062
,, ...	620	692	153,448	0·137

G. W. Westgarth‖ also gives some further costs, and states that the better the quality of wire used the larger should be the diameter of the drums and pulleys.

Colliery Cages.—Zollinger ¶ describes a two-decked colliery cage arranged for receiving four waggons.

Winding Engines.—W. Galloway** describes the compound winding

* *Journal of the British Society of Mining Students*, vol. xviii. pp. 87–90.
† *Ibid.*, p. 90. ‡ *Ibid.* § *Ibid.*, pp. 139–141. ‖ *Ibid.*, pp. 141, 143.
¶ *Praktische Maschinen Constructeur*, 1896, p. 69, with six illustrations.
** *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 207–214, with one plate.

engine at Llanbradach colliery, near Cardiff. It was designed to raise a useful load of four tons from a depth of 1500 feet in thirty seconds, with the aid of a balance rope under the cages. Particulars of the engine, &c., are as follows :—Average boiler pressure, 150 lbs., cylindrical drum, 17 by 8 feet; stroke, 54 inches; cylinders, 24 and 44 inches in diameter; weight of cages, 3 tons 1 cwt. each; weight of each tub, 12½ cwts.; capacity of each tub, 2 tons; two tubs in each cage. Some tests made without the balance rope show no particular advantage gained, but there is no loss in spite of unfavourable conditions.

C. Habermann * gives a general description of compound winding engines, illustrating his remarks by special reference to the results obtained at Idria.

A. Godeaux † describes the Gody winding engine.

H. Walters ‡ discusses the lap and lead of winding and other engines. The necessity of lead in the first strokes of winding is of little or no importance, but as the speed increases it becomes necessary. To accomplish this the eccentrics must be capable of being moved forward and backward while the engine is in motion, and this is done by an appliance devised by the author and Thornley, which is described.

W. G. Cowlishaw § gives some indicator diagrams to show the advantages of the Woodworth progressive cut-off gear for winding engines. ||

H. Wormald ¶ describes his self-adjusting rings, which are expanded by springs acting on inclined surfaces to take up wear.

An illustrated description has been published of the great winding engines of the Anaconda Mining Co.**

W. M. Morris †† has published an illustrated description of a proposed modification of the Koepe system of winding.

Berne ‡‡ describes the arrangement of the governor acting on the expansion gear in the winding engine at the Treuil pit No. 2 of the St. Etienne Colliery Company.

Prevention of Over-Winding.—F. Baumann §§ describes Roemer's contrivance for the prevention of over-winding. The cages are interlocked

* *Zeitschrift des Oesterreichischen Ingenieur und Architecten Vereins*, vol. xlviii. pp. 346-350.

† *Revue Universelle des Mines*, vol. xxxiv. pp. 86–95, with one plate.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 64–75.

§ *Ibid.*, vol. xi. pp. 111-116.

|| *Ibid.*, vol. x. p. 470.

¶ *Ibid.*, vol. xi. pp. 118–121.

** *Engineering News*, vol. xxxvi. p. 146.

†† *Colliery Engineer*, vol. xvi. p. 269.

‡‡ *Bulletin de la Société de l'Industrie Minérale*, vol. x. p. 61.

§§ *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xl. pp. 1060-1062, with four illustrations.

with disengaging apparatus that shuts off steam and puts on the brake. An illustrated description of this apparatus has also been published in the *Engineer.**

Baron E. von Wurzian † observes with reference to the Rœmer safety appliance for preventing over-winding, that it is the one which up to now has been most generally and favourably accepted. So much, indeed, has this been the case that it has been attached to sixty winding plants in the Saxon and Prussian mining districts.

Underground Haulage.—W. R. Bell and E. M'Gowan ‡ describe the haulage plant at Wearmouth colliery. There are three main haulage ways, which have handled 1300, 700, and 1000 tons of coal respectively per day. All work with some form of main and tail rope haulage, and the engines are supplied with steam from underground boilers. Detailed particulars of each system are given.

Combalot § describes the rope haulage or self-acting inclines at the Commentry collieries, where, in order to increase the output, one line is used for empties, and the other for loaded tubs, which thus always run in the same direction. By this means, plates at landings and elsewhere are avoided, and the continuations of the lines are used for storing empty or full tubs without the necessity of crossing from one side to the other. The rope is crossed and uncrossed at each journey, and the advantages and disadvantages of this method are discussed, and the arrangements of the pulleys for diminishing the rubbing of the rope are described.

Damon ‖ gives the results of some experiments made with a dynamometer carriage at these collieries. The slope of equal resistance by these experiments is reduced from 6 to 4 in 1000, owing to improvements in the rails and in the lubrication. Horses averaged 84 to 94 ton-miles.

F. Stolz ¶ describes the new endless-rope haulage installation at the Fuchs colliery at Weissstein, in Lower Silesia. The level along which the haulage takes place is 6450 feet long, and has several sharp curves.

M. Dickmann ** describes the mechanical haulage at the Eintracht colliery near Steele. Two main roads are provided with endless chains

* Vol. lxxxii. pp. 207–208, with ten illustrations.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 439.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 221–226.

§ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, pp. 82–91, with plates.

‖ *Ibid.*, pp. 92–94, with plates.

¶ *Glückauf*, vol. xxxii. pp. 445–450, with one plate.

** *Ibid.*, pp. 689–693, with one plate and sixteen illustrations.

driven by electro-motors, which are supplied from a central station at the surface.

W. Bentrop * describes, with details of cost, the mechanical endless rope haulage at the Roland colliery at Oberhausen.

According to Koepe,† the use of horses for haulage purposes in the Ewald colliery was abandoned in 1894, and in its place mechanical haulage was employed in the levels, using electricity as the source of power. The author describes the arrangements adopted. The change has resulted in a considerable saving, and the present system gives much satisfaction. The horse haulage cost twelve pfennige per ton kilometre (say 1½d.), while the electric haulage only costs 3·39 pfennige.

Electric Mine Locomotives.—T. W. Sprague ‡ describes a very large underground electric locomotive at work at Elkhorn, in West Virginia. It weighs 22 tons, and measures 17⅔ feet over all in length, stands 6 feet high, and is 5 feet in width. It runs on a gauge of 44 inches, and takes current from an overhead conductor. Three driving wheels, 32 inches in diameter, are coupled on each side. The motors are two in number, and are rated at 100 horse-power each. Average speed is 6 to 8 miles per hour, and the locomotive will take a load of 40 trucks, each weighing 4 tons, up a 2 per cent. gradient.

Baily § describes the electric locomotives and the generating plant at the No. 5 pit of the Marles collieries. A compound engine of 500 horse-power and two dynamos give the current for working eleven locomotives. In the levels the conductors are of H-section, and a trolly running on them is connected to the locomotive by a flexible connection. The armature axis is at right angles to the driving axles, which are thus driven by bevel gear. Each locomotive weighs about 3·2 tons. With a current of 35 to 38 amperes at 500 volts they develop 15 horse-power, and draw 30 tubs, each holding 10 cwt. of coal, at a speed of 9 miles.

Electricity in Mining.—I. Hale, ‖ in a paper dealing with electric mining in the Rocky Mountain region, discusses generally the advantages and application of electric transmission of power. The advantages are summed up under three heads—electricity generated by water-power,

* *Glückauf*, vol. xxxii. pp. 413–417, with one plate.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xl. p. 641.

‡ *Engineering and Mining Journal*, vol. lxii. p. 5.

§ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, pp. 41–45, with three plates.

‖ *Transactions of the American Institute of Mining Engineers;* Colorado Meeting (advance proof).

by steam at points where fuel and water are cheap, and by steam where power is used. Adverse considerations and the cost of plant are also discussed, and then attention is turned to the various systems of direct and alternating currents. The history of the applications of electricity in the Rocky Mountains is briefly given, and then general mining machinery driven by electric power is dealt with as regards hoists, pumps, drills, coal-cutters, locomotives, &c. A table is given to show details of the various plants now in use in the above-mentioned district, and a large number of illustrations are appended.

R. G. Brown * describes, with illustrations, a wooden dam built for storing water for driving an electric-power plant.

H. W. Ravenshaw † mentions some of the precautions necessary in the use of electricity in coal-mines. The points considered relate to shocks, main conductors, junction boxes, switches, motors, motor magnets, motor armatures, enclosed motors, and testing.

H. A. Mavor ‡ describes a new electro-motor he has designed for use in mines. In this, the adoption of steel for the magnets and case has not only increased the efficiency of the motor by reducing the necessary magnetising force, but by reducing the size and labour in tooling has also reduced the cost of production, while the use of a short air-space has made it possible to entirely enclose the motor without seriously increasing its weight.

H. Dubs § describes the electric rock-boring plant installed by the Bouches-du-Rhone Colliery Company in the adit level through which the waste water of the mines of the Gardanne district will flow into the sea. This level will be eight miles in length, and will also be used for cheaply transporting lignite to Marseilles. Numerous drawings of the generating station, the transmitting line, and the rock-drills accompany the paper.

R. Kennedy ‖ compares the three systems of transmitting power in mines, by steam, compressed air, and electricity, and special conditions favouring one or another of the systems are pointed out.

A description ¶ is published by Rathenau of the use which is made of

* *Transactions of the American Institute of Mining Engineers;* Colorado Meeting.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 306–320.

‡ *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, vol. xxxviii. pp. 73–93.

§ *Bulletin de la Société Scientifique Industrielle de Marseille*, vol. xxiv. pp. 45–62.

‖ *Electrical Review*, vol. xxxix. pp. 164, 257, 296, 321, 365.

¶ *Elektrotechnische Zeitschrift*, vol. xvii. pp. 402–409.

falls of the Rhine near Basel. Twenty turbines have been erected, each of 840 effective horse-power, for the utilisation of this water-power. It is intended to utilise this power over a radius of twelve miles in all directions by the aid of electric transmission. The author gives details relating to this.

Mine Timber.—W. H. Storms * has prepared for the California State Mining Bureau a special memoir on methods of mine timbering. He gives numerous illustrations of the heavy system of frame timbers used in California, and traces their development from the old post and lintel systems to the square set method introduced by Deidesheimer in the Comstock mines in 1860. Although of great service in its day, this system is likely to become less useful in the future, mainly owing to the difficulty of obtaining timber of sufficient size. Even in a wooded country like northern California, timbers 24 by 28 inches are becoming scarce.

H. W. Halbaum † discusses the economical use of timber in mines.

Hand-Boring Machines.—Details are given showing that in the Saar district the Thomas mechanical hand-drill has been utilised with very satisfactory results, and is from four to six times better than ordinary hand-drilling. A borehole 39 inches in depth was put down in hard sandstone in from 20 to 25 minutes, while ordinary drilling required 95 minutes to do this.‡

Explosives and Blasting.—A. Siersch § has applied photographic methods to investigate the safety of various explosives, and gives reproductions of the photographs, taken at various intervals after ignition, of numerous explosives, amongst which are nitro-glycerine, gun-cotton, nitro-starch, hellhoffite, blasting gelatine, gelatine-dynamite, roburite, carbonite, safety-dynamite, westphalite, dahmenite, grisoutite, progressite, and others. Photography shows that each explosive gives a distinctive flash, and both the duration and size of the flame may be determined with accuracy, this not being possible by other methods. The conclusions drawn are that each explosive gives a distinctive and

* *Methods of Mine Timbering.* 2nd edition. Sacramento. 1896. A copy of this work has been presented to the Library by Mr. W. J. Sharwood.

† *Colliery Guardian*, vol. lxxii. pp. 407–408.

‡ *Bergmannsfreund* (Saarbrücken), 1896, p. 76.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 2–8, with plates.

constant flash, other conditions being equal, and from these the safety of the explosive may be deduced. The degree of security decreases as the diameter of the cartridge and consequent size of flame increases. The flash varies with the density of the explosive, and it may be diminished by various admixtures. The following statements are made:—

(1) An increase in the length of the unstemmed portion of the bore-hole decreases—under otherwise equal conditions—the security of the blown-out shot. This observation has been already recorded by other investigators; and is now confirmed by the aid of photography.

(2) The size of the flame increases with the weight of the charge of explosive.

(3) The well-known fact that explosives with a nitrate of ammonium basis become safer in the presence of fire-damp in proportion as their carbon constituents decrease, is made evident.

(4) Even when the blasting cartridge is situated in an inconvenient position with reference to the sensitised plate, the flashes from so-called safety-explosives are smaller than those from high explosives.

From the foregoing remarks it appears that photography affords unusually great assistance in the determination of the nature and action of explosives, by enabling the relative degree of security to be quickly ascertained, and indicates to the technologist the manner (so far as composition is concerned) and method of preparing new explosives. It affords, also, an insight into the effect of various modes of stemming, and is therefore an aid that should certainly not be under-estimated in the technology of explosives.

M. C. Ihlseng * advocates the more extended use of safety-explosives in place of black powder in the American collieries, and recommends central fire cartridges and magneto-electric exploders. Coal-cutting machinery and a special workman for blasting operations are also advocated.

The same author † also discusses the improvements in blasting operations in collieries, reviewing the conditions met with, and pointing out the best practices.

F. Ritter von Říha ‡ considers the question whether the personal safety of the miner in drilling and blasting has increased or diminished since dynamite has displaced black powder. He deals with both ore

* Paper read before the Western Pennsylvania Central Mining Institute and Ohio Institute of Mining Engineers, June 1896, through the *American Manufacturer*, vol. lviii. pp. 911–913.

† *Canadian Mining Review*, vol. xv. pp. 180–181.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 354.

and coal mining, and gives statistics taken from the returns for the Prussian mines. He shows that the safety of the workpeople has increased, and not diminished.

H. W. Halbaum * severely criticises the report of the North of England Institute Flameless Explosives Committee.

In the year 1894 the use of carbonite was continued at Zauckerode and at Zwickau.† This explosive was shown to be a very safe one when experimented with by Winckaus in the experimental level at the Consolidation colliery, Westphalia. Westphalite was used by another of the Zwickau colliery companies, and also at Reinsdorf, and at these collieries its use gives much satisfaction, the output increasing considerably under certain conditions when this explosive was employed. It was found best not to place the westphalite cartridges in a warm and draught-free spot, but to put them into the air-current. At the Lugau colliery the results with the use of westphalite were less satisfactory. It was found to absorb moisture, and its explosive effect was considered inadequate. In the Lugau district but little progress has been made by new explosives, largely owing to the fact that shot-firing has been abandoned to a very large extent. At Freiherrlich, too, westphalite was not considered satisfactory, the cost being about double that of ordinary black powder, and the yield of lump coal about 10 per cent. less. The output per man and per shift diminished with its use by 1·5 hectolitre of coal. The westphalite in use was, however, considered to be of bad quality, and this has since improved.

Lithotrite No. 2 is displacing powder at the Bockwa colliery. It is stated to be free from sulphur, and to yield free oxygen when exploded.

At the Rheinelbe colliery ‡ attempts were made, in 1894, to find a suitable explosive in the place of black powder and dynamite. Roburite was first tried, but given up, as much small coal was made; and after it had been stored for three or four weeks many of the shots misfired. Dahmenite has since been found to give somewhat more satisfactory results. In dry rock the results with dahmenite were the same as with dynamite, but in damp rock less satisfactory. After long exposure to water the explosive ceased to act, and it was finally decided that for non-fiery mines its use was disadvantageous. This explosive requires stronger detonators than does dynamite. Progressite has been found

* *Colliery Guardian*, vol. lxxii. p. 317.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 317.

‡ *Ibid.*, p. 158.

more satisfactory than dahmenite. Lithotrite has also been experimented with, but apparently not with any conclusive results.

A description has been published * of wedges and explosives in mines, showing the utility of Elliot's compound wedge.

Coal-Cutting Machinery.—W. Blakemore † describes the coal-cutting machinery at Dominion No. 1 mine. Two Babcock & Wilcox boilers, each rated at 210 horse-power, supply steam for driving air compressors, which deliver air at 50° F., and compressed to 80 lbs. per square inch. The main pipe is 8 inches in diameter, and extends 2000 feet north and 1000 feet south, after which 4 and 2 inch pipes lead the air to the workings for working twenty coal-cutting machines, besides some other machinery. The seam is semi-bituminous, 8 to 8½ feet thick, with a dip of 1 in 14. Two Stanley heading machines are used, and, in spite of certain specified disadvantages, they are highly spoken of by the author. A description is then given of the Mitchell chain cutter machine, the Ingersoll-Sergeant percussive machine, and the Yoch percussive machine, and of the methods of working with these appliances. The costs are discussed, and the advantages of machine-working are summarised.

Machine and coal mining in Iowa is described by H. Foster Bain. ‡

B. Callaghan § states that in the Pittsburgh district, where coal-cutting machinery is employed, it is being seriously considered whether it would not be better to abandon the pillars altogether, owing to the difference in the cost of machine and hand labour for undercutting. This wilful waste of coal, however, is strongly to be deprecated. As worked at present the pillars are left too narrow, and cannot be worked by the machines. The author therefore advocates a plan of driving the stalls double width, leaving larger ribs or pillars, and bringing these back when all the stalls in the entry are worked.

R. M. Haseltine, chief inspector of mines for the State of Ohio, has issued in pamphlet form a paper on the use of electricity in coal-mining, which forms part of his annual report, and contains the results of a series of tests on various plants. The author finds that the lowest power to cut at the rate of one square foot per minute was 4·2 horse-

* *Engineer*, vol. lxxxii. p. 162.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 179–206, with one plate.

‡ *The Mineral Industry*, vol. iv. pp. 195–200.

§ Paper read before the Ohio Mining Engineers and the Western Pennsylvania Mining Institute, through the *American Manufacturer*, vol. lix. p. 156.

power, the machine being in this case a chain machine. The highest requirement for a machine of this type was 8·5 horse-power. The lowest requirement for a rotary bar machine on the same basis was 8·9 horse-power, and the highest 12·2 horse-power.

Working Coal.—J. Jičinský * considers the question as to what system of mining coal is most advantageous. This, he points out, must depend on the local conditions, the more or less dangerous character of the coal, and the flatness of the seams. He deals with the long-wall system, and describes a particular case in which four seams of coal are worked, giving details as to cost.

H. Gutmann † describes a method for the mining of thick seams of brown coal. The description is accompanied by illustrations.

The systems of coal-mining used in Illinois are described by J. J. Rutledge.‡

Inflow of Water from Old Workings.—An account is given of an interesting case of a sudden inburst of water from old mine workings at the Langenberg colliery, near Kohlscheid.§ In the Wurm district of the Aix-la-Chapelle field, mining has been carried on continuously since the twelfth century. Numerous old colliery workings exist, and boring in advance has been made compulsory by law when such old workings are being approached. In many places these old workings had attained considerable depth, so that the water in them is under considerable pressure. Drowning-out accidents have happened here in the past, sixty men having been drowned at the Gouley colliery in 1834, while in 1838 the Grosskaul and Vieslapp collieries were drowned out. The extreme care that is now taken, however, has since made such accidents of very rare occurrence; but in April 1896 the lower workings of several of the collieries were flooded, the water, which was under a pressure of fourteen atmospheres, breaking in through the advance bore-hole. Fortunately, no lives were lost. The pumps at some of the mines were all below surface. Another instance of the faulty nature of the pumping arrangements under conditions such as these is given in connection with the adjoining district of Holland, where a similar inburst of water

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 341–343, 357–361, and 375–377, with ten illustrations.

† *Ibid.*, vol. xliv. pp. 343–345, with three illustrations.

‡ *The Mineral Industry*, vol. iv. pp. 185–194.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 373–374; *Berg- und Hüttenmännische Zeitung*, vol. lv. pp. 172–173.

occurred. The necessity of the pumping arrangements being free from danger, should there be an inburst of water and the lower levels of a colliery be flooded, is obvious.

Pumping Appliances.—D. Baird* discusses the duty of pumping engines, and gives a short method of roughly testing the efficiency. It consists in measuring the quantity of water evaporated in the boilers when the pumps are working, and in calculating the theoretical amount of water lifted. The water evaporated is then reduced to an average coal consumption and compared with the water raised. The method is admittedly very far from being exact, but it gives a basis on which the duty can be determined. Particulars of several experiments are given.

M. de Montrichard † describes a pneumatic pump, without piston, for use in mines.

Schulte ‡ has written a detailed memoir on pumping engines, and an account § has been published of Bardeleben's electrically driven mine-pumps.

R. H. Brown ‖ describes the compressed-air plant which has been used with much success at the Sydney mines, Cape Breton, for driving underground pumps, coal-cutting machinery, and a hauling engine.

H. S. Poole ¶ mentions the advantages of compressed air for pumping, and suggests the use of underground water to prevent freezing in the motor.

C. Fergie ** gives some particulars of pumping by compressed air at Drummond colliery, Nova Scotia. The work done did not come up to that stipulated for, but an improvement was made by admitting air between the high and low pressure cylinders. The efficiency was brought up to 25¾ per cent., but less coal was consumed than when steam transmission of power was used.

Ventilating Appliances.—The Mortier fan is described and illustrated by J. von Hauer.†† The peculiarity of this fan lies in the fact that the air is not, as in other fans, sucked in through a channel into the inner portion of the fan and then blown out at the circumference, but

* *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 94–102.

† *Annales des Mines*, vol. x. pp. 101–125.

‡ *Bergbau*, vol. ix. No. 27, p. 5.

§ *Ibid.*, vol. ix. No. 32, p. 5.

‖ *Journal of the Canadian Mining Institute*, vol. i. pp. 53–55.

¶ *Ibid.*, pp. 56–57.

** *Ibid.*, pp. 58–61.

†† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 384, with two illustrations.

that it is drawn in at one portion of the circumference and blown out at another. The quantity of air delivered is proportionate to the width of the fan parallel to its axis, and by increasing this the fan may be made to deliver at will any desired quantity of air.

E. Gosseries * gives in detail the calculations for a Guibal fan.

The Ventilation of Mines.—A. Dick † describes a means of arranging the ventilation so that the fan can be used as an exhaust or a blowing fan without reversing the air current in the workings. For this purpose the air drift and chimney of the fan are provided with doors so that the inlet and outlet can be reversed. Also cross-roads are constructed near the bottoms of the shaft, and these are brought into use by doors when the air current is reversed. Only the upcast and downcast shafts change their junctions, and this has for object to avoid the clogging of the hoisting shaft by ice in the winter, as sometimes occurs in severe climates.

J. Blick ‡ draws attention to the treble entry system of mining coal, in which no trap or mine doors are necessary for the ventilation. In the systems ordinarily employed a large number of doors are necessary, and if any are left open the course of the air current is seriously affected. In the treble entry system three levels are driven, and the stalls are worked from the two outside levels. Air crossings and stoppings are then only required. A sketch is given to show the arrangement which can be used for all except thin seams free from gas.

J. Blick § discusses the effect of doors in mines on the air currents. He refers to the use and abuse of doors, and the extent to which they may be avoided.

C. Connor ‖ discusses the subject of air splits in the ventilation of mines. The number of splits is limited by the fact that sufficient air must pass through each district to dilute and carry off gas, and further, that it must give 100 cubic feet, or, in fiery mines, 1·50 cubic feet of air per minute. Regulators are used where the resistance in different splits is unequal, but as they absorb power in overcoming the additional

* *Revue Universelle des Mines*, vol. xxxv. pp. 180–198, with one plate.

† *Journal of the Canadian Mining Institute*, vol. i. pp. 165–173, with illustrations.

‡ Paper read before the Western Pennsylvania Central Mining Institute and the Ohio Institute of Mining Engineers, through the *American Manufacturer*, vol. lviii. pp. 842-843.

§ *Colliery Engineer*, vol. xvi. p. 279.

‖ Paper read before the Western Pennsylvania Central Mining Institute and the Ohio Institute of Mining Engineers, through the *American Manufacturer*, vol. lix. pp. 12–13.

resistance introduced by their use, they should be used as seldom as possible. The tendency at present is to use too many splits, and reform is needed.

H. L. Auchmuty * describes the Leith Mine and Coke Works in the Connellsville region. The geological features of the area worked, the system of mining employed, and the methods of timbering, ventilating, and drainage are described.

Safety-Lamps.—E. B. Wain † has experimented upon the use of petroleum in safety-lamps with burners of different types. Petroleum is largely used in admixture with other oils, but with a suitable burner in a locked safety-lamp there is no reason why oil with a flashing-point of 100° F. or over should not be used. The burners tested were an ordinary flat wick, Heath & Frost, J.C.M., Ashworth, Thorneburry (Barton), and the Kaye burner. A general feature in most of these is a protecting cap or cover over the pricker orifice. A table is given to show the time, comparative illumination, and cost

R. Lamprecht ‡ observes that of the hundreds of different kinds of safety-lamps which have been constructed at one time or another, scarcely half-a-dozen have been practically employed in the working of fiery mines. Success in the laboratory does not necessarily mean success in the mine, as Le Chatelier has shown statistically in connection with the Clanny and Müseler lamps. Statistics show that in practice both lamps are about equally safe, although in the laboratory the Clanny lamp showed scarcely any degree of safety at all, whilst the Müseler lamp was extremely safe. The latter, however, goes out readily, leading the workmen to open it again on their own account to relight it. The author then proceeds to discuss the Müseler lamp, and he next proceeds to a consideration of that of Wolf, illustrating the arrangements of this latter by a sketch section. He considers the improved form of the lamp to be a very safe one in practical work, and in proof of this he publishes the results of a number of comparative experiments made in a current of air between the Wolf, Dahlmann, and Müseler lamps. Modifications can be made in the Wolf lamp to admit of its use under varying local conditions.

Fire-Damp.—Sixteen samples of fire-damp, mostly from French coal-mines, examined by Th. Schloesing, jun., § contained methane, 55·6 to

* *Colliery Engineer*, vol. xvii. pp. 1–7.
† *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 104–110.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 493–498.
§ *Comptes Rendus de l'Académie des Sciences*, vol. cxxii. pp. 398–400.

96·9 per cent.; nitrogen, 2·2 to 39·8; oxygen, 0·0 to 0·8; and carbonic anhydride, 0·0 to 4·1. As a rule, the proportion of methane is more than 80 per cent. The quantity of oxygen and carbonic anhydride is usually very small, and in most cases, though not in all, these gases have been introduced during the process of collecting. The proportion of nitrogen varies widely, and is sometimes relatively high; it contains the same proportion of argon as atmospheric nitrogen does, and has most probably been derived from the air, the oxygen having been removed by combination with constituents of the coal.

Experiments in connection with the outbursts of gas in collieries have been made by Behrens.* Boreholes were put into the coal, and the gas evolved collected and measured. It contained from 95 to 99·5 per cent. of marsh-gas, from 0·44 to 1·60 per cent. of carbon dioxide, and occasionally nitrogen, the quantities met with being 3·4 and 4·5 per cent. In coal-seams which are encompassed by beds which are not porous to gas, the pressure of gas is regular throughout the whole seam; while that seam which is the least porous will show the highest gas-pressure. With an increasing depth of the borehole into the seam, an increasing pressure of gas is observable. This maximum, 14·60 atmospheres, was found in the Hibernia colliery to exist at a depth of 13 feet; while in an entirely unworked coal-seam in Belgium a gas-pressure of 42·5 atmospheres has been observed. The pressure of gas is always less at points where the seam is much inclined.

F. C. Keighley † records his experiences as a mine manager in some fiery mines in the Connellsville region, with the deductions from them.

J. S. Haldane ‡ has continued his investigations on the nature and sources of the suffocative gases met with in wells, and makes further observations on the black damp of coal-mines. A number of analyses are given.

M. Termier § has presented to the French Fire-Damp Commission a report on the Hardy fire-damp indicator. || Although the instrument will detect a very minute proportion of fire-damp, practical tests are necessary before it can be recommended for general use.

Colliery Explosions.—A Parliamentary paper was issued in June 1896 on the causes of death in colliery explosions and underground fires, with special reference to the Tylorstown, Brancepeth, and Micklefield explosions. In the first part of the report J. S. Haldane gives the result

* *Glückauf*, vol. xxxii. p. 553. † *Colliery Engineer*, vol. xvi. pp. 280–282.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 265–278.

§ *Annales des Mines*, vol. ix. pp. 577–608.

|| *Journal of the Iron and Steel Institute*, 1896, No. I., p. 379.

of his examination of the bodies of the men and horses killed at Tylorstown. Dealing with the fifty-two cases of death from after-damp, he arrives at the conclusion that the actual cause of death was poisoning by carbon monoxide. In the second part of the report the author exhaustively discusses the subject of colliery explosions.

Detailed descriptions have recently been published of the explosions at Tylorstown,* at Blackwell colliery, near Alfreton,† and at Nelson colliery, Dayton, Tennessee.‡

J. Böhm § describes the explosion which occurred at the Hohenegger colliery, Karwin, in 1895. This explosion was of an entirely different origin to any other that had previously occurred in the district. The author first describes the colliery. At the time of the explosion six seams were being mined, varying in thickness from rather more than a yard to half as much again. The output of the colliery has increased rapidly from 4430 tons in 1890 to 134,927 tons in 1894. A Pelzer fan, 9¾ feet in diameter, is used for ventilation purposes; 300 cubic feet of air per man per minute were passed through the mine in the period immediately preceding the catastrophe. Only Wolf benzine lamps were in use, with double gauze. Shot-firing was not generally employed, and was only used in places where there was little danger, and the shot-firing was only done by one special fireman in each shift. These firemen were submitted to an examination twice in each year, and the lamps used were also carefully tested. To prevent danger from dust explosions, a high-pressure water-pipe system was in course of being laid down at the time of the explosion. This explosion was very violent in character, and did great damage, in addition to which, 52 men were killed and 18 seriously injured. The explosion appears to have been a dust explosion, unaided by fire-damp, and due to careless handling of frozen dynamite. The coal-dust had the following composition:—

	Johann Seam.		Carl-Roman Seam.	
	Before Explosion.	After Explosion.	Before Explosion.	After Explosion.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ash	18·73	33·48	16·49	31·69
Volatile matter	26·31	17·79	27·60	22·96
Coke	72·97	82·20	72·39	77·10

* *Colliery Manager*, 1896, p. 143. † *Ibid.*, p. 149.

‡ *Colliery Engineer*, vol. xvi. p. 222.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 409–411, 429–433, with sheet of illustrations.

It would appear, therefore, that in the explosion a large portion of the dust was completely burnt, another portion was coked, and the remainder, due possibly to the absence of an adequate quantity of oxygen, remained unchanged. This absence of change may, however, be due to the short duration of the heightened temperature. It will be seen that the difference in the contents of volatile constituents in the dust before and after the explosion was about 7 per cent.

Coal-Dust.—G. Fowler * discusses the possibility of dealing with coal-dust by other means than watering. The points considered are the reduction of the quantity of dust produced, and its removal by a dry method. To minimise the production of dust, open-ended or lattice-framed waggons should be avoided; they should be completely emptied by revolving tipplers, and mechanical haulage alone should be used. By these means less coal is dropped and crushed in the roadways, and less dust is blown from the tubs. In order to aid in the removal, it is recommended that the walls and roof should be trimmed as smoothly as possible, and that spaces between the timbering should be filled in, and also that plastering should be extensively resorted to. The expenses of carrying out these proposals are dealt with by examples from the Cinder Hill Colliery, Nottinghamshire, and are compared with the costs of laying down extended watering arrangements, which are extremely expensive.

D. M. D. Stuart † supports at considerable length his theories regarding coal-dust as an explosive agent, and replies to the criticisms offered by Day, Durfee, Kent, and others. The theory in the author's own words is: "A colliery explosion in which coal-dust is the principal agent, comprises numerous local explosions, separate in time and in space, at irregular intervals, where the normal supplies of atmospheric oxygen are greatly increased, and caused by the explosive combustion of accumulations of hydrogen gas, derived from the coal-dust in the antecedent spaces, by a series of chemical actions of constant sequence, which produce heat for regeneration without auxiliary intervention, and are constantly reproduced along the path of the coal-dust under the conditions named." The arguments and deductions in the author's various books are summarised.

J. Ashworth ‡ discusses coal-dust and explosives, and the influence of coal-dust upon safety-lamps.

* *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 128–142.

† *Transactions of the American Institute of Mining Engineers;* Pittsburgh Meeting (advance proof). Compare *Journal of the Iron and Steel Institute*, 1895, No. I. p. 364.

‡ *Colliery Guardian*, vol. lxxii. p. 307.

M. Sarrau * has presented to the French Fire-Damp Commission an exhaustive report on accidents caused by the deferred explosion of grisoutite cartridges.

J. Verner † argues that for an explosion to occur in the absence of fire-damp, there must be intense heat and considerable flame furnished by a blown-out shot, a rapidly moving current of pure air, and coal-dust of special fineness and composition floating in the air.

The fire-damp and coal-dust question in Germany is discussed by R. Zoerner. ‡

Fires in Collieries.—J. Mayer § describes a fire that occurred at the Hermenegilde colliery, in Polish Ostrau, in January 1896, and gives plans and sections. He suggests that refuge places of large size, furnished with compressed air and other means of safety, such as breathing apparatus and electric lamps, should be provided.

Details have been published || of a fire that occurred at the Cleophas colliery, in the neighbourhood of Kattowitz, in Upper Silesia, on March 3, 1896. This colliery has been in existence since 1886, and in 1895 had an output of about 400,000 tons of coal, and gave employment to 1560 workpeople. A large number of men were killed. The ventilation was very good, about 137 cubic feet of air per workman being passed through per minute.

Health Conditions of Coal-Mining.—J. Barrowman ¶ controverts the widespread belief that the coal-mining industry is particularly unhealthy. Comparing the inspectors of mines' figures for 1855 with those for 1894, it appeared that while the number of fatal accidents had fluctuated little, maintaining an average rate over the past forty years of 1061 per annum, the output and the number of persons employed had increased almost threefold. There was no doubt that the health conditions of coal-mining had also greatly improved within the same period; but, apart from this, they wanted to know if there were diseases peculiar to coal-mining which had the effect of shortening the life of the miner,

* *Annales des Mines*, vol. x. pp. 126–132.

† *Colliery Engineer*, vol. xvii. pp. 26–28.

‡ *The Mineral Industry*, vol. iv. pp. 212–214.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 151–158, 167–173.

|| *Zeitschrift des Oberschlesischen Berg- und Hüttenmännischen Vereines*, vol. xxxv. p. 45; *Kompass*, 1896, p. 45; *Glückauf*, 1896, p. 193.

¶ *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 240–248.

or if those diseases which were common to all were aggravated by mining conditions to such an extent as to justify the statement that the coal-miner was a short-lived man. The fact that almost one-fifth of the whole male population of the United Kingdom, between the ages of 25 and 65, were miners, showed that the question was one of some consequence. But statistics relating to these matters were scanty, those for England and Wales being fifteen years old. It was shown that with one, or perhaps two exceptions, there were no diseases peculiar to the miner's calling, and these were an affection of the eyes termed "nystagmus," and, in a lesser degree, that disease of the respiratory organs which usually goes by the name of "miners' asthma." The death-rate of coal-miners from alcoholism was particularly low. On the whole, there are good grounds for regarding the occupation of the coal-miners as one of the healthiest, as, even after including deaths from accident, the mortality among coal-miners was less than that of most manual occupations. Among the contributing causes towards this result are the facts that (1) the underground temperature was equable, and, on the whole, not uncomfortably high; (2) the bulk of the coal-miners live in rural communities, and have the benefit of fresh air; (3) the coal-miner's working day is a comparatively short one, and he seldom works every day in the week.

A. Rothleitner * refers to the conditions in which the parasite Ankylostoma duodenale attacks and incapacitates miners. He shows that an outbreak of Ankylostomiasis among the men is not due to high temperature in the workings, mentioning a case at Brennberg, where a shaft opened up a new field, and was worked, without using horses, or without connecting it with old workings, for over six years without a case of the disease showing itself. Directly, however, such a connection was made and horse-haulage introduced, from 80 to 90 per cent. of the whole body of miners was attacked, and some so severely that they had to be sent into hospital at Vienna and Budapest. Microscopic investigation of the excrement of the horses employed in the mines showed this to be full of embryos of the worm in question, though the fully developed worm could not be detected. The same remedies were used as are employed in the case of tape-worms. Disinfecting and the removal of the excrement from the mine had not the least beneficial result, and, as every effort to fight the disease remained fruitless, it was finally decided to abandon horse-haulage and to remove the horses from the mine; rope-haulage has recently been

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 523.

introduced instead. This will show whether the horses alone were the cause of the disease, or whether some other embryo-bearing agent was also at work. This parasite gives rise to extreme anæmia, and in some cases may even cause death.

J. Mauerhofer * describes some above-ground improvements which have been made at the Wilczek collieries in Polish Ostrau. These relate in part to the prevention of accidents by material falling down the shafts from the surface, and consists in a cover of peculiar form which protects the men when engaged in examining the shaft. The various other improvements which are also described include safety arrangements in connection with the prevention of accidents by falls from levels into the shaft; waggon-greasing; arrangements at the Michaeli shaft, and numerous others.

The History of Coal-Mining.—O. Vogel † continues his history of coal-mining, and referring to the older writings, shows how our present knowledge of coal has been gradually developed.

R. L. Galloway ‡ has published a comprehensive history of the coal-trade from the earliest times.

H. G. Graves § deals with the advances made in coal-mining during the present century. The developments in lighting, ventilation, exploitation, winding, and other matters, are briefly described, and their effects on the present-day civilisation are shortly sketched. Iron mining, and the manufacture of iron and steel, are similarly treated.

An interesting article on the early use of anthracite coal, by W. Griffith,‖ is published in the *Bond Record*. The presence of coal was known in Schuylkill County as early as 1770. On William Scull's map of Pennsylvania, published in 1770, coal is marked near the head waters of the Schuylkill.

W. B. Thompson ¶ gives some interesting particulars of an old-world locomotive whose career has just ended. Built in the forties; after running for nearly forty years, her work as a locomotive came to an end in the winter of 1885, when the stationary engine plant at a pit being in urgent need of assistance, she was jacked up and uncoupled, grooves

* *Oesterreichische Zeitschrift fur Berg- und Hüttenwesen*, vol. xliv. pp. 507–510, with sheet of illustrations.

† *Glückauf*, vol. xxxii. pp. 350, 378.

‡ *Colliery Guardian*, vol. lxxi. pp. 967, 1013, 1059, 1105, 1155, 1201; lxxii. 15, 61, 111, 157, 207, 303, 349, 394, 440, 502, 535, 581, 642, 675.

§ "The Civilisation of our Day," edited by J. Samuelson. London, 1896, pp. 57–80.

‖ Reprinted in the *Bulletin of the American Iron Trade Association*, vol. xxx. p. 115.

¶ *The Engineer*, vol. lxxxii. p. 339.

were cut in the driving-wheel tires and wire ropes passed round them, and she then worked as a stationary engine until the closing of the pit a few months ago. She has now been broken up. The following were the principal dimensions: Cylinders, 13 in. by 22 in.; boiler, length of barrel, 11 feet 10 in.; diameter of barrel, 3 feet; thickness of plates, $\frac{3}{8}$ in.; tubes, 78; diameter of tubes, $1\frac{5}{8}$ in.; diameter of blast-pipe, $3\frac{1}{4}$ in.; total wheel base, 10 feet. The driving wheels had no flanges. The boiler was made of five plates, each extending its whole length, and lap-jointed longitudinally. No provision was made for expansive working, there being only two positions in which the reversing lever could be fixed, one for forward and one for backward gear.

Recent Progress in Mine Surveying.—J. E. Roderick, inspector of the Fifth Anthracite district of Pennsylvania, in his annual report calls the attention of colliery managers to the great need of improvements in mine plans. A plan that has only a few elevations shown on it is of little or no value. The need of accurate and complete plans is especially great in Pennsylvania, where so many mines have been partly exhausted, and abandoned for a period and allowed to fill with water, while adjoining mines are being worked, the safety of the workmen depending entirely on a barrier of coal of sometimes unknown width. In view of these facts, the inspector has announced his intention of insisting on a strict compliance with Article III. of the Anthracite Mine Law of 1891. This provides that the authorities of every colliery shall make an accurate plan of the workings on a scale of 100 feet to the inch. The plan must show the workings and passages in every seam, and state in degrees the general inclination of the strata. It must also show the number of the last survey station and date of each survey, the boundary lines of the royalty, and, in case any mine contains water dammed up, the accurate position of such dam.

E. B. Durham * gives an outline scheme for mine-surveying, describing the choice of stations, traversing underground, shaft-sinking, calculations, and plotting.

H. W. Halbaum † discusses atmospheric influences on the accuracy of magnetic surveys underground.

G. B. Hadesty ‡ describes a trustworthy and simple method for carrying a meridian into a mine. The four-wire method, said to be rapid and accurate, is described.

* *School of Mines Quarterly*, vol. xvii. pp. 209–220.
† *Colliery Guardian*, vol. lxxii. p. 443.
‡ *Colliery Engineer*, vol. xvii. p. 23.

IX.—*COAL-WASHING.*

Washing of Coal.—J. Platt * describes the Elliott washing plant erected at the Wirral colliery, near Sheffield, which deals with 11 tons of coal per hour. The coal treated consists of all that will pass through a screen with 1 inch and $1\frac{1}{4}$ inch parallel bars; the dust, peas, beans, and nuts all being mixed together. A vibromotor-screen is provided, so that a separation can be made when desired, and the fine coal or the nuts only washed; or, if another washer be erected, each kind can be washed separately, one in each trough.

The Elliott washer is designed on the principle of the trough-washer, with the difference that it is automatic and adjustable. It consists of a steel trough, 60 feet long, $1\frac{1}{2}$ foot wide at the bottom, and $2\frac{1}{2}$ feet wide at the top, the sides opening out from the bottom. This trough is fixed at an inclination of 1 in 12; and scrapers (taking the place of the fixed stops or dams used in the trough-washer) are attached at intervals of 6 feet to an endless chain, passing round sprocket-wheels fixed at each end of the trough, and caused to move slowly along the bottom of the trough from the lower to the higher end, and against the stream of water; the returning part of the chain and scrapers is supported above the trough on suitable rollers and brackets. The speed of the chain can be adjusted. Water is supplied by a centrifugal pump 3 feet in diameter, giving 150 gallons per minute to the upper end of the trough. The scrapers are 4 inches deep, and fit the trough accurately at the sides and bottom, the shape of the section of the trough enabling them to maintain this fit as wear takes place. A screen of fine mesh is provided at the lower end of the trough to receive and separate the water from the coal. Coal is supplied by an automatically feeding hopper, and a small jet of fresh water brightens the coal as it leaves the trough. The amount of ash contained in the slack before washing was 25 per cent., and, after washing, analysis showed 4·2 per cent. of ash in the coal, of which 1·20 per cent. is free dirt and 3 per cent. is natural residue.

An illustrated description has been published † of the new Soddy coal-washing plant.

E. G. Tuttle ‡ discusses the arrangements and coal-washing plant for

* *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 55–61, with one plate.

† *Tradesman*, August 15, 1896.

‡ *School of Mines Quarterly*, vol. xvii. pp. 378–400.

treating bituminous coals, giving specifications and drawings for a plant capable of handling 300 tons per day.

F. M. Jackson * gives a short account of the coal-washing plant at Brookwood, Alabama, which has a capacity of 500 tons daily. It is on the jigging system, and in many respects it resembles the Lührig washer. The coal is all crushed to ⅜ inch ; and, instead of felspar, quartz pebbles are used on the bed. The ash in the coke is reduced from 18 to 8·80 per cent., and the sulphur from 1·5 or 1·75 to 0·74 per cent. The loss amounts to between 6½ and 9 per cent. The jigs are eleven in number and have double compartments.

Illustrations † have been published of Robinson coal-washers erected at Johnstown, Pennsylvania, and near Birmingham, Alabama.

This coal-washer is also described by R. H. Richards ‡ in his review of recent progress in ore dressing.

Determining the Density of Minerals.—V. Grünberg § has devised an apparatus for the rapid determination of the specific gravities of minerals. He uses a number of solutions obtained by mixing mercury-potassium iodide with water, each solution having a specific gravity lower by 0·1 than its predecessor. Twenty such solutions are obtained in this way, varying in specific gravity from 3·17 to 1·2, and these he places in small glasses in a box kept air-tight by indiarubber.

Loading Coal.—Descriptions have recently been published || in the technical press of some of the plant on the river Thames for dealing with sea-borne coal. The coal is brought by sea-going lighters and by steam colliers from the north of England and from South Wales, and is transhipped in the river into lighters, or else is landed. Between Blackwall and Greenwich there are moored two large floating derricks, each carrying ten hydraulic cranes of three types—luffing, overside, and ordinary swinging cranes—and each can handle up to 40,000 tons weekly. At numerous wharves all these types of cranes are also installed.

J. J. Ormsbee ¶ describes the winding and tipping plant at Pikeville, Tennessee.

* Paper read before the Alabama Industrial and Scientific Society, May 13, 1896, through the *American Manufacturer*, vol. lix. pp. 187–188.

† *American Manufacturer*, vol. lix. pp. 367–368 ; *Engineering and Mining Journal*, vol. lxii. p. 129.

‡ *The Mineral Industry*, vol. iv. p. 729.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 271.

|| *Colliery Guardian*, vol. lxii. p. 630, with one plate.

¶ *Colliery Engineer*, vol. xvi. p. 280.

T. Calhoun * describes the collieries at Whitwell, Tennessee, and the mining and handling of 800 to 1000 tons of coal per day.

F. W. Rickart † discusses the surface works at collieries. He considers the situation, output, methods of screening, winding, plant, and tipping.

Coal-Dust Firing.—V. von Neuman ‡ mentions the use of coal-dust as fuel by Crampton in the paper he read before the Iron and Steel Institute twenty-three years ago, and the recent revival in the interest in this subject due to Wegener, Schwartzkopff, Friedeberg, De Camp, Ruhl, and others. With coal-dust firing it is possible to exactly regulate the air supply, no half-burnt fuel is left, and no smoke need be made. The coal must be ground to fine and uniform dust, somewhat complicated appliances are required to introduce it into the furnace, a highly heated combustion chamber is necessary, and the fine ash produced must be quickly removed. On the other hand, there is a great saving in fuel and labour. Much attention is now directed to mills for grinding the coal. All kinds of coal except lignite can be ground, but they must at least be air-dry. Disintegrators are suitable for bituminous coals, but they are sensitive to moisture. Ball-mills are adapted only for very dry and brittle coal; they also require much power. Centrifugal roller-mills find most favour with the author. Metallurgical furnaces can easily be fired with coal-dust, and it is not at all necessary, although it may be advantageous, to use a separate combustion chamber. Part of the ash is deposited in this chamber, and is there converted into a thick slag which can easily be removed. The remainder is deposited wherever the air current is slow enough to let it fall. Arrangements should therefore be made for its easy removal. Coal with as much as 44 per cent. of ash has been burnt at Portland cement works.

In May 1895 the method was introduced into the Neuman iron-works at Marktl, in Lower Austria, both puddling and heating furnaces having this method of firing adapted to them. Clay-pipe recuperators were subsequently attached to these furnaces, the waste products of combustion passing around them before escaping to the stack. The air passing through the pipes is brought in a channel under the furnace to the combustion chamber, into which it enters from beneath, through a slit at the side. Comparing the results obtained with this coal-dust firing with those obtained with the Boetius gas fur-

* Paper read before the Engineering Association of the South, April 1896.

† *Technograph*, May 1896.

‡ *Zeitschrift des Oesterreichischen Ingenieur- und Architekten Vereines*, vol. xlviii. pp. 342–346, 353–356.

naces, previously in use at the works, it was found that there was a saving of quite 40 per cent. in the fuel used, whilst the production increased by 25 per cent., and the loss of metal was much diminished. In the case of ingot iron, for instance, this loss fell from 4½ or 5 to 3½ or 4 per cent., and, with blooms, from 14 or 15 to 11 or 12 per cent. Coal-dust firing is extremely simple, secure, and satisfactory, and has the advantage that a considerable saving of labour is attained by its use, while the furnace works better.

The application of this method of firing to boilers is also described. Coal-dust explosions have not yet occurred in any instance, and are in ordinary conditions almost impossible.

B. Donkin * describes the five various methods of burning coal-dust that are now in use, and gives particulars of experiments carried out with them, more especially with the Wegener system. In the discussion, it was proposed to use the dust that collects in mines.

Utilisation of Small Coal.—In the United States the rapid increase in the utilisation of the small sizes of anthracite during the past few years has been remarkable. H. S. Thompson † ascribes this to two causes acting together—the change by furnaces and steam vessels formerly using lump anthracite, to the use of bituminous coal, and the breaking of these large sizes of anthracite into small sizes for domestic use; and, secondly, the increased favour with which the use of the smallest sizes of anthracite is regarded.

E. H. Williams ‡ shows the amount of small anthracite that is sent to the waste heap, the ways in which it has been wasted, and the methods by which it may be made available for fuel purposes.

N. G. Neare § describes the manufacture of coal briquettes.

* *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 321–338.
† *Colliery Engineer*, vol. xvi. p. 227.
‡ *Engineering Magazine*, vol. xi. pp. 644–657.
§ *Tradesman*, July 1, 1896.

PRODUCTION OF PIG IRON.

CONTENTS.

I.—*BLAST-FURNACE PRACTICE.*

Blast-Furnace Construction.—F. Büttgenbach * observes that when at the Paris Exhibition of 1865 he showed a model of a blast-furnace without the heavy walling then in use, it was treated almost with scorn, though practice has since shown that he was right. He compares the method of construction of a modern blast-furnace with that of those which were then employed, and then proceeds to a consideration of the reactions and temperatures which are met with at different heights in the furnace. He then points out that the upper portion of a blast-furnace need have no brick lining at all, a simple plate mantle being all that is required.

In an editorial note it is pointed out that Kurt Sorge in 1892 treated this question at length in *Stahl und Eisen.*

Sir Lowthian Bell † discusses some recent proposals for improving the efficiency of the blast-furnace in the United States.

A. P. Gaines ‡ describes and discusses briefly the stack of modern blast-furnaces.

A historical review of blast-furnaces has also been published.§

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 141–144.
† *The Mineral Industry*, vol. iv. pp. 415–419.
‡ Paper read before the Engineering Association of the South, April 1896.
§ *Iron and Steel Trades' Journal*, vol. lix. pp. 14–15.

Charcoal Iron Making.—Slowly but surely during the past decade the charcoal blast-furnaces in the South of the United States have gone out of blast, and now in the eastern district of Alabama there are only two in active operation, whilst a few years ago there were seven or eight centres at which these furnaces were running. Now all except the two at Shelby and Rock Run are out of blast and out of repair. One, indeed, is being rebuilt on a larger scale to use coke as fuel. This decadence is ascribed to several causes, amongst which are the depressed markets, scarcity of suitable timber, and of suitable limonite low enough in phosphorus for the manufacture of railway wheels. A still more important factor is the advance in knowledge and improvement in practice which enables coke irons to be made in the South at prices to compete with those made in Pennsylvania and Ohio. *

A description has been published by E. G. Odelstjerna † of two charcoal ironworks visited by him in the United States. One of these, the Hinkle works, is in Wisconsin, where there are ore deposits, but no coal, though the country is well afforested. The best charcoal blast-furnace in the United States is at these works. It is 6 feet 7 inches in diameter at the tuyeres, and the crucible portion is 5 feet in height. At the boshes the furnace has a width of 11 feet 3 inches, and the height from the top of the crucible to the top of the boshes is 12 feet 6 inches. At the throat the furnace is 7 feet 6 inches wide; the total height of the whole furnace is 60 feet 6 inches. From a Swedish point of view this is a very large furnace, but still not one of a size so much greater as to be comparable with its enormously larger out-turn. This is not due, either, to harder charcoal. Forest woods are used in making this charcoal, but it is very badly burnt, small, and with much dust. It must be small, however, as the ores smelted are powdery red hæmatites, which would mix badly with charcoal in large lumps. The large out-turn is due to the powdery character of the red hæmatite smelted, which favours its reduction. In the twenty-four hours the furnace treats 197 tons of ore and flux, and easily produces from 122 to 125 tons of pig iron. The ore contains about 62·56 per cent. of iron, and the limestone used as flux is 105 lbs. per ton of iron made—about 5 per cent. At the time of the author's visit to the works the charcoal used amounted to 69·4 per cent. of the weight of the pig iron made. In one month in which, owing to various causes, work was much interrupted, 4328 tons of 65 per cent. Gogebic ore, 672 tons of 62 per cent. ore, and 234 tons of 54 per cent.

* *Iron Trade Review*, vol. xxix. No. 23, p. 15.
† *Jernkontorets Annaler*, vol. l. pp. 169–404.

ore, or, in all, 5234 tons of ore containing on the average 64·1 per cent. of iron was smelted. The yield amounted to 61·57 per cent., and the charcoal used was 72·95 bushels per ton of pig iron made—about 71·6 per cent. The blast-pressure was 5½ lbs. per square inch. The furnace is supplied with two Whitwell stoves. The cost of production of the ton of pig iron is stated to be as follows:—

	Dollars.
Ore	4·37
Charcoal	5·29
Limestone	0·09
Labour	1·17
General	0·80
Total	11·72

The selling price was 12½ dollars.

Another works described is that of the Union Iron Company at Detroit. Details are given as to the dimensions of the furnace. It is smaller than the one just described, being only 50 feet 6 inches high, and 9 feet 10 inches in diameter at the boshes. About 90 tons is put through this furnace daily, its annual production amounting to about 13,000 tons. The charcoal used was 70·7 per cent. of the weight of the pig iron made; but when a perfectly white iron was produced, the quantity of charcoal necessary fell to 66 per cent. The blast is heated by two Gjers pipe-stoves, a temperature of blast of over 500° C. being obtained. The furnace is armoured with water-cooled cast-iron plates, and these, though they have been many years in use, are still without a crack. The ore charge consisted one-half of hard hæmatite and magnetite, the other half being powdery red hæmatite. The limestone used varied in quantity from 2 to 2½ per cent.

Blast-Furnace Scaffolds.—According to E. Bernard * the question of scaffolds is one of great importance to blast-furnace managers, for, while they do not at all times offer to the life of the furnace the same dangers as other accidents, they may stop or disarrange the working of the furnace for several weeks. Scaffolding should not be confounded with a clogging up of the hearth of the furnace, from which it is readily distinguished. The latter always results from an insufficiency of heat, due to an excess of ore, to imperfect reduction, or to a too refractory charge, the cause in each case being known, as well as the remedy and the means of avoiding it in future. In the case of a scaffold, on the contrary, the hearth is entirely free, and the obstruction forms in the body of the

* *Revue Universelle des Mines*, vol. xxxv. pp. 64–70.

furnace, and in consequence its exact nature cannot be directly observed. The effect produced is to arrest the passage of the gas and the entrance of the air, while combustion and the descent of the charge cease as though the furnace were stopped. The accident produces merely a hot but regular working of the furnace, and analyses disclose nothing abnormal in the composition of the furnace products, iron, slag, or gas.

An article published in 1892 by Van Vloten appears to be the only instance where the subject has been clearly treated. The author attributes scaffolds to the formation in the charge of a deposit of pulverulent carbon, derived chiefly from the dissociation of carbonic oxide in the presence of the reduced and spongy ore. This dissociation of carbonic oxide has been studied by Sir Lowthian Bell and other authorities. It depends largely upon the temperature; being very intense at 425° C., and being nothing above 900° C., where the reaction $C + CO_2 = 2CO$ becomes predominant. A relatively small amount of carbonic anhydride exists at all temperatures, and even at temperatures beyond those favourable for dissociation; blast-furnace gases are never free from carbonic anhydride.

The amount of carbon thus deposited in a furnace should not be very great, and although the charges are ordinarily impregnated by dissociated carbon, it may be admitted that this carbon completes the reduction of the ore incompletely effected by the carbonic oxide, and that the carbon absorbed by the carbonic anhydride of the carbonates may also be derived from the dissociated carbon, as well as the carbon carburetting the iron. The quantity, according to these hypotheses, should not exceed one-quarter of the total carbon consumed. In order to obstruct the furnace the amount must be ten times greater; corresponding to the dissociation of all the carbonic oxide produced during several hours. But in the case of a scaffold the analysis of the gas indicates no deficit of carbon. It has been suggested by Duvaux that the scaffold may be due to the excessive heat of the operation, and to the reduction of an excess of silica, thus rendering the slag more basic up to the point of infusibility. The case suggested of a refractory slag, on account of an excess of alumina (25 per cent.), is very rare. Ordinarily the slags are refractory on account of an excess of lime, the lime limiting for each temperature the amount of silica reduced. Moreover, infusibility of the slag stops up the crucible, an accident entirely different from scaffolding. As has been said, scaffolding does not produce a change in the furnace products. This explanation does not therefore seem tenable, and it is possible to explain scaffolding simply by the method of fusion of blast-furnace slags.

The laws of fusibility for the compounds of silica, lime, alumina, magnesia, and the metallic oxides, which constitute the slags of a blast-furnace, are not very precise. According to the experiments of Berthier the combinations of the three principal ingredients, silica, alumina, and lime, are not fusible at the blast-furnace temperatures, excepting where the ratio of the oxygen of the silica to the sum of the oxygens of the bases is between 2 and $\frac{1}{2}$, and, at the same time, where the ratio of the alumina to the lime is comprised between the limits of 0·3 and 1. The more fusible come near to the case where the first ratio equals 1 and the second 0·4, corresponding to ordinary slags made with the furnace working cold; the least fusible slags correspond to the extreme ratios, where the silica or the bases are in excess. A combination of bases, magnesia, oxides of iron and of manganese, not in excess, and other things being equal, increases the fusibility slightly.

The slags are rendered refractory in a hot furnace by an excess of silica in the charcoal furnace, and by lime or alumina in the coke furnace. The point of fusion continues to rise with this excess, which seems to be dissolved rather than combined. The slags have not a definite composition, experiments indicating that basic slags, cooled below their fusing point, do not solidify as a whole, but that the excess of base precipitates. Reciprocally, if L be a refractory slag made at a high temperature from a coke fuel, fusing at a temperature T, b an excess of bases, $L = l + b$; l being a fusible mixture at a temperature t, which is near to a state of cold working. If such an intimate mixture L be heated progressively, the part l begins to fuse when the temperature t is reached, the fused portion and the portion saturated with a base in its presence separating, and a portion is thus constantly at its limit of fusibility; the remainder of the mass remains in a pasty state until the temperature T is reached, when the residue b is dissolved, fusion becomes complete, and the whole mass becomes fluid.

In a furnace the materials burn progressively from the throat to the bottom, and at a level towards the base of the boshes the mixing of the materials and the temperature produces fusion. In the refining process the temperature in the crucible being in the neighbourhood of t, the total or partial fusion is possible only at the level mentioned. In a hot process for the mixture L, the fusion may commence, if the mixture is sufficiently intimate, at a higher level, at the temperature t by the fusion of the more fusible part l in the presence of an excess of the bases b. It will be an incomplete and pasty fusion between the two levels; but at the temperature T the fusion is complete.

The mass of partially fused materials, and the bases agglomerated with the fuel, constitute the scaffold of the furnace. This effect should always be manifested in the case of a furnace working hot; in fact, a furnace always works less freely under such a condition. It may be partial or complete according to the previous mixture of the materials. It is by means of such a preliminary mixture that the well-known effects upon the scaffold may be brought about, also by the character of the materials treated, by the method of charging, and particularly by the profile of the furnace. There are two methods of opening up a clogged furnace :—

(1.) By blowing into the boshes near the belly by means of one or more supplementary tuyeres. Combustion and fusion are thus carried on in the agglomerated mass, which becomes loosened and falls in a short time.

(2.) A more speedy remedy consists in blowing as violently as possible into the crucible, opening the tapping-hole, and suddenly stopping the blast. This operation repeated several times often produces a slipping of the suspended material. The effect is produced more rapidly the colder the air, and it is probable that the agglomerated pasty mass of the scaffold cools and solidifies, and on so doing contracts and becomes loosened. Indeed, scaffolds seem to resist for a long time if simply acted on by the furnace gases passing near the scaffold, and they resist treatment in the furnace with hot-blast.

An account has recently appeared * of two experiences with a chilled hearth in a blast-furnace. In one case the water supply failed and the tuyeres burnt out. After thirty-six hours new tuyeres were put in and the blast turned on full, with the result, that after the material at the bottom had burned out, the chilled material above fell in and choked the furnace. An oil blow-pipe was used at the slag-notch, and in an hour one tuyere was started to work, then the other tuyeres were burned out and started. In the second instance a ring scaffold slipped and choked the hearth. The oil blow-pipe was again used with success, first at the slag-notch and then at the tuyeres. A steam-drill was also used at the tuyeres.

The Smelting of Titaniferous Iron Ores.—A. Ledebur † discusses the experiments of A. J. Rossi.‡ After describing these experi-

* *Iron Age*, vol. lvii. pp. 1123–1124.

† *Stahl und Eisen*, vol. xvi. pp. 310–313.

‡ *Journal of the Iron and Steel Institute*, 1896, No. I. pp. 401–404.

ments, he passes to a consideration of Rossi's conclusions as to the advantages due to the presence of titanium in the ores on the character of the product obtained. He considers these unproved, but believes that titanium will exert on iron a similar influence to that exerted by silicon, although this is still uncertain. That Rossi, in some of his experiments, obtained white iron and not grey, was due, not to the fact that the ores smelted were titaniferous, but to the conditions under which the experiments were carried out. Only white iron was possible with the furnace working rapidly and at a low furnace temperature.

Explosions in Blast-Furnaces.—F. E. Bachman * considers that the explosions which occur in blast-furnaces are primarily caused by the deposition of carbon. Gas drawn from the furnace 10 feet below the stock-line was passed over samples of different ores, with the result that much larger amounts of carbon were deposited on ores from the Mesabi district than on other ores. The clogging of the charge thus produced will, in a very few seconds, cause the pressure to rise so rapidly below the top of the furnace, that, when the gas does make its way through, it does so with explosive violence. The remedy is to use a larger proportion of other ores in the burden.

Full details of these experiments referred to by F. E. Bachman are given by O. O. Laudig.† The methods employed are indicated above, and the results for thirty-three different samples of ore from various localities are given in detail in tabular form. These show the comparative friability of the ore as indicated by the percentage remaining on sieves of different meshes after crushing, and the size of the particles, the specific gravities of the ores, the losses and the amount of carbon deposited on heating the ore in a stream of blast-furnace gas, and the full analyses of the ores.

These views are partly supported by G. R. Johnson,‡ who finds that soft brown hæmatites of South-west Virginia act in a similar manner; but he thinks that the explosion is a combination of a bad slip and a true explosion of a combustible mixture of gases. It is suggested that lower furnaces, with a double bell, and an inward slope of 1½ inch per foot above the boshes, should be used.

* *Iron Trade Review*, vol. xxix. No. 17, p. 7.

† *Transactions of the American Institute of Mining Engineers;* Colorado meeting (advance proof).

‡ *Iron Trade Review*, vol. xxix. No. 19, p. 9.

Stopping the Tap-Hole of Furnaces.—An illustration has appeared* of a new form of "notch gun," an appliance for stopping tap-holes of furnaces. It consists of a cylinder filled with clay, which is brought by a crane into position, where it is secured in place by a hook. Steam is then turned into the rear end, and expels the clay without the intervention of a piston.

American Blast-Furnace Practice.—J. L. Stevenson† gives particulars of American blast-furnace practice, with drawings of blast-furnace plant for a minimum nominal make of 200 tons per day of twenty-four hours per furnace, from ores containing 50 per cent. of iron, for which the furnaces were designed. He gives specifications of plant of two furnaces built in the United States.

H. L. Haldeman,‡ in a historical sketch, describes the Chickies furnace, one of the oldest in Pennsylvania, and mentions the furnaces which used anthracite coal in Lancaster County, in that State. Out of these fifteen only three are now at work.

Casting Pig Iron.—Illustrations have appeared§ of apparatus designed by H. R. Geer, of Johnstown, for casting pig iron. It consists of an endless belt or chain of chill moulds, mounted on a carriage so that it can run from one furnace to another. The metal as it is tapped is run directly into the moulds, and when they are full the belt is moved forward. When the belt or chain, which runs in a vertical plane, turns downwards at the end, it discharges the pigs on to a railway truck.

The Manufacture of Iron in Southern India.—W. Maylor‖ traces the history of the manufacture of iron and steel in Southern India, referring to the attempts made to manufacture steel in 1818, 1830, 1833, and 1853. He gives a section of the blast-furnaces most suitable for the ores of Southern India. Hot blast was used for a few years; but as consumers of the pig iron preferred cold-blast iron, the hot-blast was abandoned. To supply one blast-furnace, it was necessary to clear one acre or two acres of moderately heavy forest per day. It was eventually

* *Iron Age*, vol. lviii. p. 357.

† *Engineer*, vol. lxxxii. pp. 25–27; 80–82.

‡ Paper read before the Lancaster County Historical Society, through the *American Manufacturer*, vol. lix. p. 154.

§ *Iron Trade Review*, vol. xxix. No. 32, pp. 8-9. Compare Mr. Hibbard's paper in this volume.

‖ *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. cxxvi. pp. 383-386.

found impracticable to collect more than 1500 tons of charcoal for each works per annum, equal to the production of about 750 to 800 tons of pig iron for one blast-furnace. About 5 tons of suitable wood were required to produce 1 ton of good charcoal, weighing 19 to 20 lbs. per cubic foot. It was advisable to use a pressure of blast equal to 3 lbs. per square inch (which is considerably higher than is used for blast-furnaces in Austria and in Sweden), because of the small size of the ore. The cost of the pig iron was 50 to 60 rupees per ton at the port of shipment, and each furnace produced about 6 tons daily.

The iron ore which was used was a rich magnetic oxide of iron, and yielded on an average 55 to 60 per cent. of metal in the blast-furnaces. It was found on or near the surface of hills in small nodules, no underground operations being necessary.

Ironworks.—According to R. Seidel,* the Gleiwitz ironworks has now exceeded its first hundred years of existence. In 1789 the then King of Prussia, Frederick William II., sent Count Reden, with an Englishman of the name of Wilkinson, to inspect the ironworks of the United Kingdom, and on their return the King made a grant of £15,000 for the purpose of building the ironworks in which the existing one had its origin. The works was completed in 1796, the construction having been in the hands of Wedding (the grandfather of Professor Wedding) and Bogatsch. On September 21, 1796, the first coke furnace was blown in. This was the first coke blast-furnace in the continent of Europe.

Illustrated descriptions have been published † of the Briansk Co's. Alexandroffsky ironworks, and of the Glengarnock ironworks.‡

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

Luxemburg Pig Iron.—H. Wedding § discusses the progress made in the metallurgy of iron during the year 1895. He first refers to the proposal that has been made to institute a careful examination of analytical methods, and then passes to a consideration of the fresh finds of

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, vol. xliv. pp. 373–386.

† *Iron and Steel Trades' Journal*, vol. lviii. p. 430, with two illustrations.

‡ *Iron and Coal Trades' Review*, vol. lii. pp. 281–284.

§ *Chemiker Zeitung*, vol. xx. pp. 425–429.

iron ore made during the year, and the developments of the existing supplies, together with the increasing use of finely divided ore. The direct reduction methods are next touched upon, and the blast-furnace method is then dealt with.

He gives the following analyses of the pig iron and slag produced in Luxemburg:—

Mark MM.

Pig Iron.	Per Cent.	Slag.	Per Cent.
Sulphur	0·05 to 0·10	Silica	31·5
Silicon	0·5 „ 1·0	Alumina	18 to 19
Manganese	1·3 „ 1·6	Lime	43
Phosphorus	1·7 „ 1·8	Magnesia	2
Carbon	3·7 „ 3·9	Manganous oxide up to	1·9

Mark OM.

	Per Cent.		Per Cent.
Sulphur	under 0·15	Silica	30 to 31
Silicon	0·5 „ 1·5	Alumina	18 „ 19
Manganese	0·3 „ 0·9	Lime	43 „ 44·5
Phosphorus	1·0 „ 1·8	Magnesia	2·0
Carbon	3·2 „ 3·7	Manganous oxide up to	0·8

Other matters dealt with are furnace gases, stoves, analysis, physical and chemical properties, &c.

Foundry Pig Iron.—A. Ledebur * observes that the fact that silicon was not a troublesome constituent of foundry iron, but one that was absolutely necessary, only became understood towards the end of the seventies. The author considers that he was the first to propose that foundry pig iron should be purchased not by the appearance of its fracture, but by its chemical composition, and that the price paid for it should increase in proportion to its contents in silicon, and in inverse proportion to its phosphorous and other deleterious constituents. As the composition of the metal varies, so its treatment and uses must vary too, as West has pointed out, and then the foundryman will no longer call it "bad" when it does not happen to suit his particular purpose. Cast iron increases in strength if submitted to repeated shocks insufficient to produce fracture; this is due, Outerbridge thinks, to a rearrangement of the particles of the metal. The fact that it does so increase in strength

* *Stahl und Eisen*, vol. xvi. pp. 433–436.

he has shown by the aid of a very large series of experiments—some thousand in number. Ledebur considers that the cause of the increase in strength lies in the fact, that the tension induced by the more rapid cooling of the outer skin of the metal is got rid of by any after treatment that eliminates it.

Russian Pig Iron.—J. Kowarsky * publishes the following analyses of pig iron from the Dnieper works, Russia :—

	Foundry Pig Iron.	Bessemer Pig Iron.	Forge Pig Iron.	Spiegeleisen.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	3·8	3·8 to 4·3	3·3 to 3·9	3·98 to 4·8
Graphite	2·2 to 2·9	2·8 ,, 3·2	0·2 ,, 0·3	...
Silicon	1·5 ,, 2·2	1·2 ,, 1·7	0·4 ,, 1·3	...
Phosphorus	0·6	0·06 ,, 0·08	0·09	0·09 to 0·20
Sulphur	0·01 to 0·02	0·03 ,, 0·06	0·09	...
Manganese	0·20 ,, 0·35	1·5 ,, 2·8	1·2 to 2·7	6·2 to 29·0

Analyses are also given of the slags produced in the manufacture of these pig irons. They are as follows :—

	From Foundry Iron.	From Bessemer Iron.	From Forge Iron.	From Spiegeleisen.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silica	28·2 to 32·5	32·5 to 34·0	36·0	33·2 to 36·9
Alumina	8·6 ,, 10·6	9·5 ,, 10·5	8·9	7·7 ,, 8·9
Lime	50·9 ,, 53·5	45·2 ,, 48·1	45·0	31·5 ,, 42·7
Magnesia	1·9 ,, 3·0	2·6 ,, 4·0	3·9	4·6 ,, 8·6
Sulphur	3·2 ,, 4·2	3·4 ,, 3·7	2·7	2·3 ,, 3·2
Manganese	0·10 ,, 0·15	...	...	3·1 ,, 12·8

As given by the author, Bessemer pig irons and forge pig irons are grouped together. In the case of the slags from spiegeleisen, the higher was the percentage of manganese in the alloy, the higher also was it in the slag, and in the three cases given it approximately amounted in the slag to one-half of the percentage contained in the spiegeleisen produced.

* *Stahl und Eisen*, vol. xvi. p. 863.

III.—*BLAST-FURNACE SLAG.*

Calculating Slag Compositions.—R. Welcke * discusses the method of calculation and the composition of blast-furnace slags. Ferrosilicon, with 12 per cent. of silicon, corresponds, he states, with a slag with approximately the composition—

Silica.	Alumina.	Manganous Oxide.	Lime.
33·6	26·0	1·0	33·0

the oxygen of the base being to the oxygen of the acid in the proportion of 0·8.

For grey pig iron an aluminous slag is best; and this should not contain too much silica, especially if, with little manganese in the charge, the passage of sulphur into the iron is to be avoided, in which case with hot working an excess of lime should be employed. With little alumina in the charge, white manganiferous pig iron can readily be produced; care must be taken in this case, so as to avoid the passage of unreduced ferrous oxide into the slag, with the then possible reoxidation of the reduced manganese, and its passage in the form of oxide into the slag. The composition of the slag should fall within the following limits:—

	Per Cent.
Silica	30 to 35
Alumina	10 ,, 5
Manganous oxide	5
Lime and magnesia	55 to 45

The author considers that calculations in which the alumina is considered as a base, and capable of replacing as such equivalent quantities of lime and magnesia, are inaccurate, and may lead to undesired results. Practice shows that it is rather the relation of the alumina to the other bases which should be considered. Platz considers that the character of a slag is dependent on the formula $\frac{SiO_2 + Al_2O_3}{CaO + MgO + FeO + MnO}$, all other bases of the formula RO being added to those mentioned. Silica and alumina, the author observes, may replace each other in a slag, but not alumina and lime, and he quotes in proof of this the following slag analyses. No. I. would in practice necessitate a lime addition, as it is a glassy slag that can be drawn out into threads; No. II., on the other hand, is stony with rough surface, and of a short character when hot:—

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 135–137.

	I.	II.
	Per Cent.	Per Cent.
Silica	37·1	35·4
Alumina	16·7	9·2
Lime	38·5	47·2
Magnesia	1·9	2·3
Manganous oxide	0·7	0·4
Ferrous oxide	0·4	0·4
Calcium sulphide	4·1	4·6
Totals	99·4	99·5

Both slags are monosilicates, the oxygen of the acid to the oxygen of the base being as 1 to 1. If to I. is added 17 per cent. of limestone containing 50 per cent of lime, then the percentage of lime will be about the same as in II., and the silica and alumina also attain approximately the same percentages; but the slag is no longer a monosilicate, as it has the ratio, oxygen of acid to oxygen of base = 0·79 to 1. The author, in calculating the composition of a slag, therefore adds together the silica and the alumina on the one hand, and the bases on the other, instead of adding the alumina to the bases.

With regard to the question as to the mode of occurrence of sulphur in slag, the author points to the strong smell of hydrogen sulphide in the steam resulting when molten slag is granulated in water. This process reduces the percentage of sulphur in a slag by about 10 per cent., and this he attributes to the sulphur being in combination with calcium in the slag, a simultaneous percentage of manganese assisting this combination. In foundry iron slags, manganese is almost entirely wanting, and yet nearly the whole of the sulphur is in the slag; but Becher adds that with certain irons manganese must also be present if the sulphur is to pass into the slag and not into the iron.

Removing Slag from Blast-Furnaces.—G. Kroupa * considers the methods in use in the United States for the removal of the slag, in the blast-furnace plants smelting ores other than those of iron in the Western United States.

Granulation of Blast-Furnace Slag.—J. Bares † observes that an analysis by B. Maloch showed that in 1000 parts of a water in

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 453–457.

† *Časopis pro Prumysl Chemický*, vol. vi. p. 189; *Chemiker Zeitung Repertorium*, 1896, p. 210.

which blast-furnace slag had been granulated there were dissolved (parts), SiO_2, 0·4260; $CaSO_4$, 0·7491; $FeSO_4$, 0·1083; $MgSO_4$, 0·4482; Na_2SO_4, 0·1778; NaCl, 0·0376; Na_2SiO_3, 0·6930; CaS, 0·2707; and H_2S, 0·0472. It had a temperature of from 48° to 56° C., and is stated to be of value in the treatment of rheumatism.

Slag Bricks.—In France * these are made in the following manner. The slag from all the furnaces is allowed to flow through a rotating trommel, which separates the slag into dust, nuts, and lumps. The nuts are washed to separate the small pieces of coke that are mixed with them. These form from 4 to 5 per cent. of the total fuel consumption in the furnaces. The dust is ground with slaked lime in the proportion of 10 to 3. The mixture is then pressed into bricks. Those bricks which are only sun-dried may be used for light walling. From a cubic metre of the mixture of lime and the slag dust, 2500 bricks can be made at a cost of a shilling the hundred. The longer the bricks are stocked the harder they become, and they ought not to be used for six or seven months after manufacture. A brick-press of ordinary type is employed.

IV.—*FOUNDRY PRACTICE.*

Cupola Practice.—E. Kirk † discusses cupola practice, and gives as the amount of fuel used for melting a ton of iron in the pot-furnace 1 ton, in the reverberatory 10 to 20 cwt., and in the cupola from 172 lbs. To obtain this low result with the cupola it must be well constructed and managed, and should be run to its fullest capacity. The tuyeres must be placed low, and the charging doors high. The rule for charging a cupola is to put 3 lbs. of iron to 1 lb. of fuel on the bed, and then 10 lbs. of iron on each lb. of fuel in the charge. The author advocates placing the tuyeres very low, from 2 to 6 inches above the sand bottom, as the iron can be drawn off hotter and more fuel is saved. Charging-doors are now often placed 10 to 15 feet above the bottom, or even higher. At the Carnegie works a height of 30 feet is used. The height of the melting zone is then discussed, and the dulness of the melted iron is ascribed to the use of too large a percentage of fuel.

* *Badische Gewerbezeitung; Thonindustrie Zeitung*, 1896, p. 285; *Stahl und Eisen*, vol. xvi. p. 600.

† Paper read before the National Convention of Foundrymen, through the *Iron Trade Review*, vol. xxix. No. 22, pp. 15–16.

Illustrations have been published * of the usual forms of drying-ovens, cranes, cupolas, and blowers; of the new foundry † of the Niles Tool Works, Hamilton, Ohio; and of a foundry ‡ with a capacity of 9 tons a day.

Centre Blast for Cupolas.—T. D. West § advocates the use of a central tuyere in cupolas, and gives illustrations of some of the forms adopted by him. For large cupolas over 50 inches in diameter the central tuyere is fixed and the drop bottom is in two halves, so as to fall clear. For smaller cupolas the tuyere is fixed to the bottom and falls with it. The usual tuyeres at the side are also employed, and preferably the air-supply to these and to the central tuyere is controlled by separate valves. Experience has shown that any fair quality of fireclay will serve for the central tuyere, but it is advisable to have a spare, well-dried one and its cap in reserve.

A description of West's central-blast cupola has also been published in *Engineering*.‖

Casting with Direct Metal.—T. D. West¶ deals with the manufacture of castings poured with metal taken direct from the blast-furnace. The greatest difficulty encountered is due to the variations in the quality of the metal, and to the constant liberation of kish. These led to the practice of remelting the iron in the cupola. Direct metal free from kish makes good castings, and has the advantage that the sulphur is lower than in remelted iron. Many attempts have been made to obviate the difficulties due to kish, such as skimming in the runners, and the use of reservoirs or mixers, but none are successful for varied reasons. The direct metal may be lively and fluid enough, but it loses too much heat on standing, and the evolution of the graphitic material is continuous. Direct castings are, however, often made, the metal being taken from the tap-hole by hand or other ladles. The author then refers to a process recently devised by E. A. Uehling for treating the metal in the ladle by introducing various materials to eliminate impurities.

* *Engineering*, vol. lxii. p. 297.

† *Engineering News*, vol. xxxvi. p. 45, with five illustrations.

‡ *Uhlands Technisches Rundschau*, 1896, p. 36, with one plate.

§ Paper read before the Western Foundrymen's Association, through the *Iron Trade Review*, vol. xxix. No. 26, pp. 12–14.

‖ Vol. lxii. p. 156, with ten illustrations.

¶ *Iron Trade Review*, vol. xxix. No. 36, p. 11.

The Grading of Foundry Iron.—At a recent meeting of the Western Foundrymen's Association,* the following questions were discussed:—Are foundries generally noticing an irregularity in the grading of foundry pig iron? If so, does this irregularity exist more generally in Northern than in Southern iron? Does it apply to both charcoal and coke irons, and is any of the difficulty traceable to an extreme desire on the part of the furnaces to supply their Bessemer pig iron trade at the expense of foundry trade? Many of the contributors to the discussion thought that Southern pig irons were often more irregular, but there was no general tendency to ascribe the difficulties to the demand for the Bessemer qualities. It would appear that the inability of foundries to support a chemist, and the increasing tendency to grade by analysis instead of by fracture only, is causing some trouble; but it was pointed out that the effect of the composition of the coke especially, and of treatment generally, has oftentimes a greater effect than the original nature of the iron itself.

The Value of Metalloids in Cast Iron.—M. M'Dowell † discusses the subject of mixing various brands of cast iron in order to produce suitable material for different castings. The effect of different elements is summarised, and then analyses are given of five brands of iron with which the author proposes to experiment by mixing them in various proportions for cupola-melting. The proposed proportions are set forth in a number of tables. In this way it is intended to make a large number of castings, in which the different impurities will vary in relation to others which are to be kept constant. In the discussion which ensued, a committee of three was appointed to experiment on these lines for the Western Foundrymen's Association.

Compressed Air in the Foundry.—C. W. Shields ‡ deals with the supply of compressed air in the foundry. Poppet-valves are very generally used in the compression cylinder, and it is advantageous to place them on the ends of the cylinder instead of in the cylinder head, which is then left free for cooling jackets. It is, however, preferable to use the piston inlet-valve. An efficient regulator or governor should be provided. A belt-driven compressor is to be preferred to one driven by

* *Iron Age*, vol. lvii. pp. 966–967.

† Paper read before the Western Foundrymen's Association, through the *Iron Trade Review*, vol. xxix. No. 30, pp. 12–17.

‡ Paper read before the National Convention of Foundrymen, through the *Iron Age*, vol. lvii. pp. 1143–1144.

steam under ordinary circumstances, but a steam-driven compressor is often most economical. The pipes and reservoirs are then briefly considered, together with the application of compressed air to cranes, hoists, pig breakers, moulding machines, sand blast, &c.

C. W. Shields * also deals with the economy of using compressed air in the foundry, and gives some examples of the time saved and the air used in cranes used for manipulating flasks during mouldings. A description is given of a 20-ton travelling crane with a 40-foot span worked by compressed air, which is supplied by a continuous hose 480 feet long. This is carried by slides, so that it can fold up into loops when the crane is at one end of its travel. The applications to sand blast, moulding machines, testing machines, and the transmission of power generally are mentioned, and different types of air-compressors are discussed, and the chief requirements for an efficient form are given. It is stated that the used sand from the sand blast is mixed in the proportion of one to four of other sand, and used for moulding purposes.

G. A. True † deals with the use of compressed air for hoisting in the foundry. In a foundry turning out 30 tons daily, it is estimated that 80 horse-power hours are employed in blowing, 50 for hoisting, and 18 for mills and miscellaneous work. Various types of hoisting appliances are considered, beginning with the direct-acting hoist, consisting of a suspended vertical cylinder, with a simple piston working in it. To increase the length of stroke the cylinder is made double, the internal cylinder working as a piston during half the stroke. In other cases the direct-acting cylinder is placed vertically. Other types of cranes and hoists are driven by a compressed air motor. A pressure of 60 to 100 lbs. is found to be convenient for general use.

Electric Foundry Cranes.—A. E. Outerbridge ‡ considers that the factors of primary importance in foundry cranes are safety, speed, range, steadiness, and economy in action. The jib crane and the overhead crane have distinct, but often overlapping, functions. As a rule, for light and miscellaneous work the first is preferable, and the second is most useful for heavy work. The transmission of power is also considered, and it is held that electric overhead cranes have the balance of advantage.

* Paper read before the Western Foundrymen's Association, through the *Iron Age*, vol. lviii. pp. 619–620.

† Paper read before the Western Foundrymen's Association, through the *Iron Age*, vol. lviii. pp. 572–574.

‡ Paper read before the National Convention of Foundrymen, through the *Iron Age*, vol. lvii. pp. 1142–1143.

Moulding.—T. D. West * discusses green, dry sand, and loam moulding. At one time all massive castings were made in dry sand or loam moulds, but now it is recognised that the face need not be harder than in small moulds, so that green sand is usually employed at the present time. For large castings in green sand it is a good method to form all pouring gates with dry sand cores, and the same material may be advantageously used for projecting parts. Skin drying is also referred to for green sand moulds; in this case, a loamy facing sand is required. Green sand moulding is generally considered the most economical, but in many cases there is less risk with dry sand. Loam moulding has not advanced to any extent. It is used for large or intricate castings, and it does not demand complete patterns.

T. Addison † describes the method of moulding and casting a 30-inch one-eighth bend pipe weighing 3200 lbs. A special form of core iron is shown to avoid danger of breaking by irregular expansion. The bottom half of the core is made in dry sand, and the upper half may be in green sand.

A description has been published ‡ of the methods of making the moulds for and casting a large column 35 feet long, and tapering from 20 inches in diameter to 30 inches between the cap and base, which were 3½ by 6 feet square. The total weight was 17·1 tons.

R. T. Watson § describes some curious accidents in foundries, one caused by a rat burrowing through the mould to get at the flour-facing, and another caused by freezing of the mould before pouring. A heavy casting successfully made with inefficient appliances is also described.

The Pattern-Shop.—E. C. Will ‖ describes the methods he uses for storing and assembling of patterns. The shelves are three high, averaging 5 feet wide, and are supported at intervals of 8 feet. The gangways are 2½ to 3 feet wide. The shelves are lettered A B C from below upwards, and the compartments are numbered. The articles on the shelves are thus known by a letter and a number, and are catalogued. Larger patterns are placed in rows on the floor. Blank forms are used for ordering and assembling the patterns, and these show the machine to

* Paper read at the National Association of Foundrymen, through the *Iron Trade Review*, vol. xxix. No. 20, pp. 11–12.

† *Iron Moulders' Journal*, through the *Iron Trade Review*, vol. xxix. No. 34, pp. 8–9.

‡ *Iron Trade Review*, vol. xxix. No. 25, p. 11.

§ *Iron Moulders' Journal*, through the *Iron Trade Review*, vol. xxix. No. 26, pp. 10–11.

‖ Paper read before the Foundrymen's Association, May 6, 1896, through the *Iron Trade Review*, vol. xxix. No. 20, pp. 12–13.

be made, and the symbols for each part, together with the date, moulder's name, and other particulars. The blanks are entered in a day-book.

Pattern-Shop Costs.—A. Sorge,* junior, discusses at considerable length the question of pattern-shop costs, and gives a number of blank forms for use in keeping the accounts. It is shown that it is not sufficient to consider only the cost of material and labour used in making the pattern, but that its economic value depends on the product made from it. The author has previously discussed † foundry costs, and has shown how these should be calculated in relation to the weights of the castings, and he now uses the same factor as a basis for the system of costs in the pattern-shops. The items to be considered are labour, materials, and expense. The latter includes all charges against the shop, except those included properly under labour and material. To keep a record of these, differently coloured blanks or tickets are used for each class of work in the workmen's hands, and the figures from these are classified and summarised in further blank forms. With the figures thus obtained it is shown how the cost of any individual pattern can be found on a comparable basis.

The Phœnix Roll Works.—The Phœnix Roll Works at Pittsburgh cover about three acres, and are the largest works in the United States for the manufacture of different kinds of chilled and other rolls. There are two foundries. One occupies a building 40 by 268 feet, and is equipped with two 40-ton and one 20-ton power cranes, besides four 20-ton hand cranes. It contains four casting-pits, two drying-ovens, one cupola, and three reverbatories of 30, 18, and 12 tons capacity. The second foundry is 60 by 140 feet, and has three 80-ton steam jib cranes. The casting-pit is 20 feet wide and 30 feet deep. There is one large cupola and two 30-ton reverbatory furnaces. The ladles hold from 8 to 15 tons, and rolls up to 36 inches are cast in chills weighing 36 tons each. The machine-shop is 398 feet long and 40 to 57 feet wide. It contains thirty-two lathes, and a number of heavy boring, grinding, and polishing tools. A 60-ton electric crane commands part of the shop. The works possess a laboratory, and make their own analyses. Old rolls are melted up and cast into pigs for sale. The daily melting capacity of the firm is 180 tons.‡

* *Iron Age*, vol. lvii. pp. 1407–1413.
† *Journal of the Iron and Steel Institute*, 1895, No. II. p. 490.
‡ *Iron Age*, vol. lvii. pp. 967–968.

PRODUCTION OF MALLEABLE IRON.

Best Yorkshire Iron.—On October 8, 1896, before the Metallurgical Department of the Glasgow and West of Scotland Technical College, E. Windsor Richards* delivered a lecture on the manufacture of "Best Yorkshire Iron," with special reference to the process of ironmaking in the Low Moor ironworks, Yorkshire. Low Moor had passed its hundredth year of usefulness, the first blast-furnace having been started in 1791, and the first cast of iron being made in August of that year. He briefly sketched the development of the works up to the present time. Four years ago a new furnace was started, which was probably the largest cold-blast-furnace ever constructed. It was 70 feet high, and had a capacity of 10,700 cubic feet. The old furnace produced from 75 to 80 tons of iron in the week. He mentioned the interesting fact that he had proved that the new Low Moor furnace worked much more satisfactorily when producing 350 tons per week than when it only produced 200 tons. The works at Low Moor owed their existence to the high quality of the coal, and to the quality of the ironstone found on the estate. Over 3 tons of ironstone were required to make a ton of pig iron, and this was the most expensive of the materials used.

Mechanical Stokers for Puddling and Heating Furnaces.—At the works of the Piqua Rolling Mill Company, Ohio, mechanical stokers are used for firing the puddling and heating furnaces. An illustration of a puddling furnace thus fitted, with some tests, have been published.† The coal is fed from an external hopper by a screw to the bottom of the fire, so that the distillation products rise through the top incandescent layer. The air-supply is fed in through tuyeres placed under the coal-feeding device, and opening into the fireplace near the bridge. Of a comparative test with two similar furnaces, one stoked by

* *Iron and Steel Trades Journal*, vol. lix. p. 514.
† *Iron Age*, vol. lvii. p. 1125; *Iron Trade Review*, vol. xxix. No. 17, pp. 8–9.

hand and both furnished with boilers, the following particulars are given :—

	Hand.	Machine.
Time of six heats . . . hours	56·0	54·5
Coal used . . . . . . lbs.	23,939	21,443
Iron charged . . . . . ,,	36,500	37,250
Total output . . . . . ,,	31,585	32,990
Output per lb. of coal . . ,,	1·31	1·54
Waste of iron . . . . per cent.	13·5	11·2

Particulars of the boiler results are also given, showing an advantage in favour of the machine-stoking.

Electric Fusion of Iron.—B. H. Thwaite * deals with the fusion of iron in crucibles by electricity. He shows that a great saving in heat is effected as compared with ordinary furnace methods, while oxidation is also avoided.

The History of Iron.—At the Liverpool meeting of the British Association on September 21, 1896, W. Ridgway read a paper on "The Starting Point of the Iron Age in Europe." He said that the origin of the iron age was one of the most important points in European archæology. Scandinavia could not be its place of origin, for there the iron age began later than the Christian era. And it was admitted that the iron age came in *per saltum* in the Swiss lake dwellings, in Italy, Greece, France, and Britain. Hellstadt, in Austria, was, in fact, the only place in Europe where articles of iron were found gradually replacing those of the same kind made in bronze. Near the Hellstadt Cemetery lay one of the most famous iron-mines of antiquity. It was from this Austrian centre that the use of iron spread into Italy, Switzerland, Gaul, Spain, Greece, and Eastern Germany among tribes that were using bronze weapons and implements, and Tacitus was the authority on this point.

In the discussion which followed, it was pointed out that there were instances of the use of iron in Scandinavia, gradually superseding bronze, in the fifth or sixth century B.C. There was, too, very early evidence of the use of iron in Syria, whence it spread to Greece, and the spread of iron in Britain was earlier than was generally supposed, as early, in fact, as the sixth century B.C., especially in Ireland.

The oldest notice of the use of iron in China is in the *Yü Kung*,

* *Iron and Coal Trades' Review*, vol. lii. p. 159.

which may be called the geographical section of the Book of History, and dates from 2200 B.C. Iron was then obtained in the province of Szechuan, where salt and natural gas are now worked by deep borings. Steel is also mentioned in the same passage under the name *lou* or *leu*, and later in the third century before the Christian era it is mentioned under the name *chü*, which is an analogous word. At that time it was produced in the province of Honan, in the Nanyang prefecture. Pliny, it is stated, mentioned Chinese iron in the form of swords.*

Some iron originally hammered into plates but now deeply rusted by age was found by Dr. K. Humann in the ruins of a temple at Magnesia, Asia Minor.† From part of it a memorial tablet was made some time ago and presented to Bismarck. The iron is supposed to date back to a period between 200 and 300 B.C. It approximates to steel in its composition, though closely akin to malleable iron. Various analyses showed the following percentages :—

Carbon.	Phosphorus.	Sulphur.	Slag.
0·20	0·016	...	...
0·23	0·0223	trace	...
0·061	0·025	...	1·01

A historical account has been published ‡ of the wrought iron industry from the earliest records to the present time.

S. H. Holland has published in the *Antiquary* § an illustrated article on the extinct iron industry of the Weald of Sussex. It is curious to note the indications of the industry still remaining in names of places; in the still existing Hammer Ponds, and the forests which are little more than forests in name, their timber having long since been consumed in the old iron furnaces. The author states that the last Sussex ironworks were those of Ashburnham, dismantled in 1828.

* *North China Herald*, through the *Engineering and Mining Journal*, vol. lxii. pp. 101-102.

† *Iron Trade Review*, vol. xxix. No. 23, p. 13.

‡ *Iron and Coal Trades' Review*, vol. lii. pp. 620-622.

§ *Antiquary*, July 1896.

FORGE AND MILL MACHINERY.

Hollow Steel Forgings.—H. F. J. Porter * deals with the manufacture of hollow steel forgings made on a mandrel. As the walls of such forgings are comparatively thin, the metal must be thoroughly worked, homogeneous throughout, and absolutely without defect. Only open-hearth steel of suitable carbon contents can be used, and the phosphorus and sulphur must not exceed 0·04 per cent. The best practice requires that the ingot shall be double the length of the finished forging, and that from 25 to 30 per cent. of the top end of the ingot should be cropped off. Whitworth fluid compressed steel is to be preferred. After cropping, a hole nearly the size of the finished forging is bored through it. The hollow ingot is then reheated and worked up in a hydraulic forging press, a loose-fitting mandrel being inserted. The pressure must be sufficient and continued long enough to cause the metal to flow uniformly, and hammers cannot be used. The work may have to be reheated during treatment, and when finished it is annealed and tempered if necessary. The effect of light and heavy hammers, and also the comparative strength of solid and hollow shafting, is then considered, and it is shown that hollow-forged shafts are stronger than solid shafts of the same diameter, owing to the more thorough working of the metal, its higher quality, and the absence of the interior portion of the ingot. Various examples of hollow forgings are then mentioned, amongst these being a hollow nickel steel shaft for the warship *Brooklyn*. This is 17 inches external diameter, 11 inches internal diameter, and 39 feet long, weighing 19,112 lbs. The tensile strength is 94,245 lbs., elastic limit 60,775 lbs., elongation 25·5 per cent., and reduction of area 60·58 per cent.

Cassier's Magazine † also contains a paper on "Making Steel Forgings in America," by H. F. J. Porter, which is illustrated with eighteen illustrations of the shops and products of the Bethlehem Iron Company.

* Paper read before the American Society of Mechanical Engineers, May 1896 through the *Iron Age*, vol. lvii. pp. 1231–1234, with illustrations.

† Vol. x. pp. 83–98.

Forge at Douai.—An illustrated description has been published * of the new forge at Douai. The works are designed for the manufacture of heavy forgings.

Steam-Hammers.—An illustration is published † of an open frame 12-ton steam-hammer for forging wheels. The diameter of the cylinder is 38 inches, and its stroke 6½ feet. The piston rod is 21 inches in diameter, and passes through a second bearing below the stuffing-box. The hammer is double acting. The standards are tubular, being built up of riveted boiler-plate, and are splayed out towards the base.

H. K. Landis ‡ describes the failure of two piston-rods and the present nickel steel rod used in the steam-hammer at Bethlehem, Pennsylvania, which is rated at 125 tons. This represents the weight of the piston, piston-rod and tup, or the total falling parts. The first two rods weighed about 13 tons each, and were made from high carbon open-hearth hydraulic-forged steel, with a four-inch core running the entire length, and an external diameter of 16 inches. The length of the first rod was 37½ feet, and of the second 38 feet. The usual stroke was 6 or rarely 8 feet, but accidentally the first rod was allowed to fall 16 feet, resulting in bending it. The second rod was made with a lower carbon steel, but a drop of ten feet bent it more seriously than the first. For the third rod, nickel steel was used of the following composition:—

C.	Mn.	P.	Si.	S.	Ni.
0·34	0·67	0·03	0·139	0·041	3·129

The tensile strength was 92,000 lbs per square inch, elastic limit 49,000 lbs., reduction of area 40 per cent., and elongation 21 per cent. The diameter of the rod was made 17 inches instead of 16 inches, and the core 8 inches in diameter, 22 feet from the top, then a taper of 4 inches, and then a 7-inch bore for 18 feet 5 inches to the bottom. The thickness of the walls thus varies from 4½ to 5 inches, and a greater section is given at the lower end, where the previous rods had failed. Illustrations are given to show the constructions and attachment of the ends of this rod, and the bending of the two previous rods are given as curves, and in tabular form.

Hydraulic Presses.—C. A. Ångström § mentions the points which are to be borne in mind when constructing welding presses. Many types

* *Génie Civil*, vol. xxix. pp. 209–212, with one plate and two illustrations.

† *Iron Age*, vol. lviii. p. 617.

‡ *Iron Age*, vol. lvii. pp. 1357–1358.

§ *Jernkontorets Annaler*, vol. li. pp. 23–45.

of such presses are to be met with in practice, the differences lying mainly either in the mechanical arrangement of the press itself, or in the way in which the water is admitted under the necessary pressure during the working of the press. This is either derived from high-pressure pumps, or is obtained by the help of accumulators or of intensifiers. Of accumulators there are two kinds—those with compressed air or with ordinary weight pressure. The former appears to be the more advantageous of the two in the case of a large press. When using an intensifier, steam may be employed as the primary driving power, as well as compressed air or water. In England high-pressure conduits are employed, in which the water is usually under a pressure of 50 atmospheres. The author then proceeds to a more detailed consideration of four types of construction that are frequently employed in practical work:—(1) of Tannett, Walker & Co. of Leeds, with weight-accumulators; (2) of Tweddell, Plant & Fielding, with, in a 1000-ton press, the water forced direct into the pressure cylinder by pumps; (3) that of Baare, with compressed air accumulators; and (4) that of Davy. The details of these he describes by the aid of numerous illustrations.

Shearing Machinery.—Illustrations appear in *Stahl und Eisen* * of a hydraulic plate shears erected at the Oberbilker Roller Mills at Düsseldorf. The illustrations show it in about one-fortieth of its natural size, and they are accompanied by a description.

Illustrations have been published † of eccentric shears for red-hot blooms at the Mossend Ironworks.

Rolling-Mills.—J. T. Brassington gives a general review of rolling-mills used for iron and steel, with the object of showing the progress that has been made in size and output during the last twenty or thirty years.‡

Illustrations have been published § of the recent improvements in the construction of rolling-mills.

Illustrations are published ‖ of a three-high universal mill built by a German firm. The greatest width of rolls is 31½ inches, and the smallest 5·9 inches. The shortest length treated is 15¾ inches. To bring metal

* Vol. xvi. pp. 405–407, with one plate.

† *Engineering*, vol. lxii. p. 123, with three illustrations.

‡ *Iron and Steel Trades Journal*, vol. lviii. p. 534.

§ *Dingler's Polytechnisches Journal*, Sept. 1896, pp. 225, 248, 273, with 60 illustrations.

‖ *Stahl und Eisen*, vol. xvi. p. 369, with one plate.

of such short length into the mill, a special arrangement of driven rolls has been designed.

Illustrations * are given of a rolling-mill at Duisburg on the Rhine. This is intended mainly for beams, and, though erected in 1889, is still considered one of the best of its kind.

An illustration has also been published † of a rolling-mill fitted with an electromotor for driving the screwing gear. The motor is mounted on the top of one housing, and drives both screws by a transverse shaft and bevel gearing, the speed being first reduced by spur gearing. A brake wheel is attached to the armature, and is surrounded by a brake strap which is automatically loosened when current is turned on, and tightened when it is cut off.

The Bicheroux rolling process, intended for shaped iron of special section for which ordinary mills are unsuitable, is illustrated and described in *Stahl und Eisen.* ‡ The process is also described by Schrödter.§

* *Stahl und Eisen*, vol. xvi. p. 525, with illustrations.
† *Iron Age*, vol. lvii. p. 1466.
‡ *Stahl und Eisen*, vol. xvi. p. 308, 9 illustrations.
§ *Ibid.*, p. 322.

PRODUCTION OF STEEL.

CONTENTS.

I.—*THE CARBURISATION OF MALLEABLE IRON.*

The De Laval Direct Process.—The De Laval direct process, F. H. Daniels * states, is being developed in Sweden. It consists in mixing pulverised iron ore with carbon, probably in the form of peat, and heating the mixture in a rotating cylinder, after which it is brought into contact with a powerful electric arc which reduces the ore to metallic iron. The melted iron flows into a large and highly heated furnace, where it can be manufactured directly into steel or cast into suitable form for further treatment.

Cement Steels.—In the process for crucible-steel melting devised by S. Kern,† the steels for the trials were prepared in the steel-foundry of the St. Petersburg Naval Port (New Admiralty) in the following manner. As there was no special furnace available for cementation, experiments were made using plumbago crucibles 13 inches high and 10½ inches in diameter instead of cementation boxes. The crucibles were heated in ordinary crucible coke furnaces usually employed for copper-melting. Two experiments were made, and each time about 50 lbs. of cement steel was obtained.

1. *Charging the Crucible.*—On the bottom was placed a layer of charcoal 4 inches in thickness; next a layer of rounds, obtained from

* *Iron Age*, vol. lviii. p. 635.

† *Chemical News*, vol. lxxiv. p. 5.

the punching of open-hearth steel ship plates (0·18 per cent. of carbon). On this layer 2 inches of charcoal was placed, next a layer of rounds, a layer of 2 inches of charcoal, a layer of rounds, and finally, the top was covered with charcoal. A burned clay plug was fitted and well plastered with clay.

2. *Operation of Cementation.*—The crucibles were heated in the furnaces for four and a half hours, and during this time, at the middle of the operation, a fresh charge of coke was made. At the end of the operation, the lids of the furnace were covered with clay all over the seams; the crucibles remaining in the furnace, to cool, for twenty-four hours. On opening the crucibles, all the three layers of punchings were found to be melted together, and an ingot was found at the bottom of the crucibles which could be easily broken. It had an earthy-greyish fracture, with numerous spots of graphite.

Analyses of several pieces from this ingot made at the Obouchoff Steel and Cannon Works, St. Petersburg, showed the metal to contain, on the average, 3·60 per cent. of graphite and 0·56 per cent. of combined carbon. The cement steel, mixed with soft wrought iron and other ingredients employed in the process, is melted in crucible-steel furnaces for the production of chisel-steel.

Contents of Phosphorus and Sulphur in Crucible Steels.—S. Kern * gives the following table, drawn up after many years of work with crucible steels.

Formula for the Contents of Phosphorus and Sulphur in Crucible Steels.

	P+S. Per Cent.
Tool steel—	
Best	0·03
Fair	0·04
Middling (rather suspicious)	0·05
Projectiles	0·03

In this sum of the phosphorus and sulphur contents, it is preferable to have the sulphur as low as possible, say, 0·019 per cent. (maximum).

	P+S. Per Cent.
Steel castings—	
Best	0·05
Fair	0·08
Suspicious	0·10

All castings must be annealed.

* *Chemical News*, vol. lxxiv. p. 76.

Tool Steel.—W. Metcalf * has published in book form the results of his twenty-seven years' experience of the manufacture of crucible steel. He gives in detail the fundamental principles governing the treating, working, annealing, and tempering of such metal. Besides this, a chapter is devoted to the different alloy steels, and to the effect of the ordinary metalloids upon the physical qualities of the harder varieties of tool steel.

II.—*THE OPEN-HEARTH PROCESS.*

Open-Hearth Steel Plants.—In a steel plant at Etna, Pennsylvania, a 30-ton open-hearth furnace was built to replace a furnace of smaller capacity under somewhat constricted conditions with regard to the crane arrangements. A straight casting pit with a travelling ladle carriage was therefore employed. The carriage is moved by an endless chain, and an automatic brake to stop the engine when the ladle was in position for pouring was devised, but was not found to be necessary. Illustrations are given.†

A plan of two open-hearth steel plants at Coatsville, Pennsylvania, has recently been published.‡ One plant will have one acid and five basic furnaces, whilst the other has four acid and two basic furnaces. Boiler-plate, tank, and flange steel are made, and are rolled direct from the ingots by 120 and 126-inch mills. The capacity of the two works combined is 120,000 tons yearly. The building is 325 feet in length, 100 feet in width, and 30 feet high to the roof trusses. The stock space is 75 by 325 feet, and is 11¼ feet above the top of the mill level. The charging floor is 22 feet wide, and the furnaces are placed in line. Each furnace occupies a space 46 by 15 feet, the hearths being 21½ by 12 feet, and having a stack 4½ feet in diameter by 90 feet high. A casting-pit 27¾ feet in diameter and 8 feet 5 inches deep serves each pair of furnaces, and contains a 50-ton hydraulic crane. Two 12-ton hydraulic cranes lift the ingots from each pit. Fifteen Smyth gas producers supply gas, and are capable of burning 24,000 lbs. of coal per twenty-four hours.

* "Steel: a Manual for Steel Users." New York: J. Wiley & Sons. Price 2 dollars.

† *Iron Age*, vol. lvii. p. 1367.

‡ *Ibid.*, pp. 1355–1356.

Open-Hearth Practice.—Remarkable open-hearth practice is reported at the No. 1 furnace of the Phœnix Iron Co., Phœnixville, Pennsylvania, covering a period of exactly six working days, of twenty-four hours each. The furnace commenced charging at six o'clock on Sunday evening, March 29, and the twenty-first heat was tapped and furnace bottom fixed on Saturday afternoon at 5.55. The mixture was one-third pig iron and two-thirds scrap, and owing to presence of high silicon in the pig iron, 1000 to 1500 lbs. of ore was used in each heat. All the heats were run into dead soft grade, 0·10 to 0·12 carbon. The twenty-first heat was in the furnace only four hours and fifty minutes, this time being taken from the first metal charged until the tapping-hole was opened. The weight of the ingots made in this run was 463 tons. The actual loss from metal charged to ingots produced was 6·6 per cent., but the weight of pit scrap and skulls reduced this to less than 5 per cent. All heats were charged by hand labour exclusively. This furnace was originally built for 15 tons capacity, and the charges subsequently increased without enlarging the furnace in any way.*

The Bertrand-Thiel Open-Hearth Process.—According to J. Hartshorne,† for something over two years past a new development of the open-hearth process has been in operation at the works of the Prager Eisenindustrie-Gesellschaft at Kladno, in Bohemia. It was devised and perfected by Ernst Bertrand, general superintendent, and Otto Thiel, steel-works superintendent. The results which the inventors wished to obtain were to increase the product per furnace, to reduce the amount of refractory materials and additions used, to enable a poorer and more varied quality of stock to be employed, to improve the quality of the material produced, and to render the control of the operations and product more certain. In all of these objects they have been successful, and have thereby considerably reduced the cost of manufacture and increased the value of the finished material.

The plant consists of one 12-ton and one 20-ton furnace. Through an incident of construction the smaller furnace stands some distance behind and to one side of the larger furnace, and at a height of about 10 feet above it. The relative position of the furnaces suggested the experiments by which the process was developed, and also enabled it to be

* *Iron Trade Review*, vol. xxix. No. 16, p. 16.

† *Transactions of the American Institute of Mining Engineers*, Sept. 1896 (advance proof).

thoroughly tested. The plant is not as convenient and suitable as one specially designed for the process would be; nevertheless the pecuniary and technical results have warranted its continuous operation.

The process consists essentially in dividing the charge between the two furnaces, tapping the metal from the upper into the lower one, and removing the slag from the metal during its progress from one furnace to another. Both furnaces are at work on the basic system, although this is not an essential feature of the process. Pig iron high in phosphorus and silicon is charged into the upper furnace with a small portion of the scrap, if desired, and also a certain quantity of ore and limestone. The remainder of the scrap is charged into the lower furnace, together with pig iron and a small quantity of limestone. A little ore is also added if necessary. The upper furnace is first charged, and the metal is melted and made hot. This takes about three hours. By the end of this time the metal is hot and fluid, the silicon is all in the slag, and the carbon and phosphorus are to a considerable extent eliminated. It is then ready for tapping. The lower furnace is charged about two hours later than the upper one. By the time the charge in the upper furnace is ready for tapping, the metal in the lower one is also fluid.

The primary furnace is then tapped, the slag being carefully skimmed off the metal as it passes down the trough and prevented from entering the secondary furnace. As soon as the two metals mix together a very lively reaction ensues, which quiets down in about a quarter of an hour. The phosphorus is then below 0·03 per cent. in the bath. The heat is finished by addition of ferro-manganese or spiegeleisen, and is ready to be tapped if no further improvement in quality be desired. Fifteen minutes longer in the furnace brings the phosphorus below 0·02 per cent.

It is evident that the character of the charges in the two furnaces will vary materially with the local conditions affecting the supply of raw materials. Where scrap is cheap and plentiful, more will be charged into the primary furnace, and the charge in the secondary one may contain no pig iron at all. Where scrap is scarce and dear, none will be charged into the primary furnace, and only the commercially available amount will be used in the secondary furnace. In all cases the material higher in silicon, phosphorus, and sulphur will be charged into the primary furnace, and the available amount of purer material will be charged into the secondary furnace together with the necessary amount of other stock.

According to the present practice the charges are as follows :—

	Upper Furnace.	Lower Furnace.
	Tons.	Tons.
Basic Bessemer pig iron	7·5	1
Steel scrap	5·5	8
Limestone	0·15	0·8
Magnetic iron ore	0·20	none

The lower furnace is charged about two hours after the upper one. The metal in the upper furnace contains 0·6 to 0·9 per cent. of phosphorus when tapped into the lower one, while the metal contained in the lower furnace is already highly oxidised and very low in phosphorus. After uniting the two metals, it takes fifteen to twenty minutes to reduce the phosphorus to 0·020 per cent.

At present from five to six heats, of 22 tons of metal charged, are made at Kladno every twenty-four hours. The lower furnace is empty more than half the time. It is evident, therefore, that with two primary furnaces at least ten heats could be made in the twenty-four hours. The present capacity is from 110 to 132 tons (charged weight) in twenty-four hours, and this will be doubled by the use of another 12-ton primary furnace which is now being erected and will soon be at work.

In order to show in more concrete form the advantages derived from the new process, the following extracts, taken from the Kladno reports and cost sheets for the five months immediately before and after its adoption, are here given.

The total cost of conversion was reduced 27·50 per cent. The output increased 72·3 per cent.; but some of this was due directly to the use of a second furnace. A fair allowance for the product of this furnace would be 20 tons per twenty-four hours. If this be allowed for, the increase in product was 20·20 per cent. The increase under present practice is much greater, being about 50 per cent. A plant of two 10-ton furnaces and one 20-ton furnace would have a capacity of at least ten heats in twenty-four hours, as shown above. This would give from 200 to 240 tons of ingots. A very good product from these furnaces, run separately, would be five heats in forty-eight hours from each, or 2½ per day. This would give 25 tons from each of the small furnaces and 50 tons from the large one, or a total of 100 tons of ingots. It seems reasonable to suppose, therefore, that the capacity of such a plant would be more than doubled if run under the Bertrand-Thiel process.

Besides these advantages, which are shown by actual figures, it is

claimed that the amounts of deoxidisers and recarburisers used are also reduced, and that the loss is smaller. The work of the ten months contained in the table does not show any material difference between the two processes so far as average loss is concerned, the difference in favour of the Bertrand-Thiel process being only about 0·10 per cent. It is reasonable to suppose, however, that with more experience this feature may be improved. The secondary furnace contains only a small amount of slag, which is comparatively free from oxide of iron at the end of the operation. There should be, therefore, less loss of metal as oxide; and a smaller amount of oxide in the bath, both of metal and slag, and it should require a smaller amount of deoxidiser to free the steel from red-shortness. This point, however, is somewhat difficult to determine, since so many specifications require more manganese in the steel than that which is required to make it roll well. The control of the quality of the finished product is very complete. Steel is made to specifications within a range of from 0·05 to 1·25 per cent. of carbon. The phosphorus can be run down below 0·02 per cent. with ease; the sulphur is kept below 0·003 per cent., and the manganese can be regulated very closely. As an instance, it may be stated that a large amount of steel has been made containing 0·80 to 0·90 carbon. This steel was used for bayonets for the Italian army, and the results were very satisfactory.

The work of the past year has shown that from 65 per cent. to 75 per cent. of the sulphur is removed by this process.

The Wellman Charging Machine.—Illustrations have appeared * of the Wellman charging machine which is in use at the Homestead Steel Works. The material to be charged is loaded into boxes 6 feet long, 2 feet 2 inches wide, and 1½ foot deep. Three of these boxes are placed on the front platform of the machine, which is then run in front of the furnace on rails of 13⅝ feet gauge, being driven by a 25-horse power electric motor. On the base of the machine are four standards, carrying at their top two girders 8 feet apart, on which runs a trolley. To a bracket depending from the trolley is pivoted an arm with a T-head to fit a recess in the rear end of the boxes. The driver is carried on a platform at the rear end of this arm, and he runs the arm carrying the box into the furnace and overturns it, these operations being controlled by electromotors.

Cost of Basic Open-Hearth Plant.—The minimum size of a comparatively economical basic open-hearth plant, according to a recently

* *Iron Age*, vol. lviii. pp. 397–398.

published article,* may be taken as not less than two 20-ton furnaces when worked as an adjunct to a tin-plate mill. Ingots should be cast of such a size as to be readily rolled down to tin-plate bars in a bar mill. The size best adapted for this work is a three-high 24 by 72 inch mill, and at least two sets of rolls should be provided, so as to make bars of two widths. Ingots are to be bottom cast, in moulds six to ten on a plate, and each mould should contain two ingots, one above the other. The ingots should not exceed 200 to 250 lbs. The rolls should have an edging pass for use when the reduction is half accomplished. The details of production are estimated as follows:—

	Tons.
Weekly charge	520
Weekly product, ingots	480
Annual product allowing 10 per cent. waste, and 45 working weeks	21,060
Annual out-turn of bars, allowing 5 per cent. waste in bar mill	20,007
Annual out-turn of black plates, allowing 20 per cent. waste in plate-mill	16,006

The cost is summarised as follows:—

	Dollars.
Charge 11,700 tons pig iron at 11 dollars	128,700
Charge 11,700 tons scrap at 8 dollars	93,600
Conversion, 21,060 tons ingots at 6 dollars	126,360
Interest on furnace plant, 60,000 dollars	3,600
Operating bar-mill 1·75 dollar on 20,000 tons of bars	35,000
Interest on bar-mill plant, 15,000 dollars	900
Cost of 20,000 tons of tin-plate bars	388,160

This brings out the cost of bars as 19·40 dollars, or £4, 0s. 10d. per ton.

Experiments on the Manufacture of Steel.—A demonstration,† extending over several days, was recently made at the Ashbury Carriage Works of a process for the manufacture of steel, the chief feature of which is the employment of a mixture of dephosphorising agents to rapidly eliminate phosphorus and sulphur, the actual conversion not occupying more than three minutes. The chief elements of this mixture are nitrate of soda and magnetic iron sand, which are used, with common salt and black oxide of manganese, to form a base to the converting vessel before the molten pig iron is run in from the cupola. When the molten iron is brought into contact with the mixture a violent reaction takes place, the two become mechanically and automatically mixed, the

* *Tin and Terne*, through the *Iron Trade Review*, vol. xxix. No. 23, pp. 14–15.
† *Colliery Guardian*, vol. lxxii. p. 738.

slag is skimmed off, and the converted metal is run into an open-hearth furnace, where it is refined for an hour and a half to two hours. It is then tapped into a ladle in the usual way. The process is that devised by B. P. Stockman.

Steelworks.—Brief descriptions are given by E. G. Odelstjerna * of the works of the Otis Steel Company of Cleveland, and of other steelworks in the United States. The Otis Company possesses open-hearths of 15 to 18 tons capacity, and a 25-ton Bessemer converter, besides other furnaces, &c., and three trains of rolls. The Bessemer pig iron used contains 2 per cent. of silicon, but the ingots produced contain too many blowholes.

The Solid Steel Company, Alliance, possesses a small and new steelworks intended solely for steel castings. It possesses two open-hearths, and one of the very small Bessemer converters; but this does not appear to have been used with any success.

Another works visited was that of Singer, Nimick & Co., of Pittsburgh. This was originally erected in 1848, and includes eight puddling furnaces, a 10-ton open-hearth, fourteen steam-hammers, ten trains of rolls, and a number of heating and welding furnaces, as well as several crucible steel furnaces. The annual out-turn of steel is about 20,000 tons.

The best open-hearth furnace that the author saw was at the works of the Carbon Iron Company, at Pittsburgh. It was armoured with quarter-inch boiler plates, and anchored with double T iron. The doors shut well, and both doors and valves are moved by hydraulic pressure or by compressed air. The best steel, he states, is made at the works of the Crescent Steel Company, at Pittsburgh. Dannemora iron is used. Five crucible steel furnaces are in use. One of these is of 60-pot capacity, two of 36, and two of 25. The first is divided into ten divisions, separated by thin dividing walls from each other, each division taking six crucibles arranged in two rows. Gas and air enter along the side of the furnace. This works also possesses two open-hearths, one used for the burning of dolomite, and the other, of 10-ton capacity and basic-lined, for the manufacture of the raw steel for the crucible steel manufacture. While the steel formerly produced from the Dannemora iron contained 0·020 per cent. of phosphorus, now this percentage is but 0·010, or even less.

The Pennsylvania steelworks, of Steelton, possesses four large blast-furnaces using a mixture of anthracite and coal as fuel. In addition

* *Jernkontorets Annaler*, vol. l. pp. 169–404.

there are two 7-ton and three 8-ton converters, with five trains of rolls and many open-hearths on the hydraulic-tipping principle. These were not at work. Oil firing is used for them. The works possesses a 25-ton electric-driven ingot crane. A 25-ton acid-lined open-hearth was making excellent steel castings. It was stated that no aluminium was being used, but the author doubts this. New basic-lined open-hearths have been erected that are to take 55-ton charges. When being charged the furnace is tipped, and the charging openings turned upwards.

The Homestead steelworks of Carnegie & Co. was also visited. The workpeople employed number 25,000, and they produce about 1,500,000 tons of pig iron, and more than the same quantity of merchant iron and steel yearly. The Bessemer shop is a very small one, containing only two 5-ton converters; but there are two large open-hearth plants with from 12-ton to 35-ton open-hearths, one set being arranged for the acid and the other for the basic process. The rolling-mills and the rest of the plant generally are described at some length. Armour-plates are made from charges to which 3·4 per cent. of nickel is added in the form of its oxide. On top of the layer of nickel oxide, which is reduced in the ordinary way with charcoal powder, is placed first the scrap and then the pig iron. The finished steel often contains 3·25 per cent. of nickel.

The Duquesne steelworks, near Cochrane, produce solely rails and billets, using two 7-ton Bessemer converters for this. The works possesses fourteen groups of soaking-pits and four trains of rolls. Its out-turn is about 235,000 tons a year. So large an out-turn of rails and billets from the two converters used is due to a constant succession of charges. The next charge is fully blown by the time the preceding one has been emptied into the moulds. When a ladle requires repairs, it is removed and is replaced by another. It is only when a converter stands in need of some repairs that there is any cessation of work. How this is repaired rapidly is not stated. A new bottom was put in in five minutes and two seconds in the author's presence. How this was done is described.

The works of the Latrobe Steel Company, Latrobe; of the Johnson Company, Johnstown; and of the Cambria Iron Company, of Johnstown, are also described.

F. C. G. Müller* has published a history of the Krupp steelworks. Adorned with six photographs from paintings by A. Montan, and with

* *Krupps Guss-stahlfabrik.* Dusseldorf: A. Bagel. 1896. Price 25s. The original is in the library of the Institute.

numerous highly artistic illustrations by Felix Schmidt, this handsomely bound volume covers 170 large quarto pages. It gives a clear description of Krupp's world-famed works and of its products. At the Essen establishment alone every working day, it is stated, 3500 tons of coal is consumed; and after a concise description of the physical and chemical properties of iron and steel, accounts are given of the puddling works, the crucible steelworks, the open-hearth furnaces, the Bessemer plant, the celebrated steam-hammer "Fritz" and rolling-mills, and, lastly, the engineering shops, in which more than 800 lathes are at work. Descriptions are also given of the firebrick works, in which 115 tons of firebricks and as many as 2500 crucibles are produced every day; of the various blast-furnace plants on the Upper and Lower Rhine; of the iron ores at Bilbao, and of the steamers carrying the ore from Spain to the works.

A description has also been published * of the Firminy steelworks. The plant comprises one blast-furnace, several open-hearth furnaces, puddling furnaces, and a 40-ton steam-hammer. There is one blast-furnace, with the blast heated by three Whitwell-Cooper stoves. The out-turn is 60 tons daily. In the steelworks there are two acid-lined 20 to 25 ton furnaces, with independent gas-producers. Steel is cast into ingots mounted on trucks. The same building also contains three crucible furnaces, each holding thirty pots and turning out 3000 tons yearly. A second department contains one 15-ton open-hearth furnace, four 8 to 12 ton furnaces, and one 3 to 4 ton furnace. The rolling-mills are also shortly described, and plans of the works are given.

III.—*THE BESSEMER PROCESS.*

History of the Bessemer Process.—R. H. Thurston † has published a biographical sketch of Sir Henry Bessemer, in which he traces the early history and development of the Bessemer process. The memoir is accompanied by portraits of Sir Henry Bessemer at different periods in his career, by photographs of a Bessemer converter house at night, of a test-piece from a Bessemer steel gun, of the effect of twisting a Bessemer steel bar, and by six drawings of the converter.

* *Comptes Rendus Mensuels de la Société de l'Industrie Minerale*, 1896, pp. 69–77, with three plates.

† *Cassier's Magazine*, vol. x. pp. 323–337, 435–447.

The Walrand-Legénisel Process.—R. M. Daelen * refers historically to the origin of the Walrand-Legénisel process of Bessemerising in small converters, and in connection with this deals with the Clapp-Griffith and Robert processes, referring to the work of Delattre. The Robert works, which were started in Paris, had to be closed down, but were restarted. The manager of the works, M. Tropenas, subsequently patented a modified form of converter with the blast entering in part below and in part above the surface of the metal, and erected a 2-ton converter on this principle in the United Kingdom. The author observes, however, that these two processes differ very little theoretically, while in practical work they do not differ at all, and he sees no advantage in the Tropenas method. He deals generally with the relative advantages of the small Bessemer process.

The Tropenas Converter.—Further particulars, with illustrations, of the Tropenas converter, have recently appeared.† The converter is mounted on trunnions, and has two rows of tuyeres, both at one side of the vessel. The lower set is on the level of the bath; and the upper set, of somewhat smaller size, and supplied with air by a separate blast-box, are used to give the air necessary for complete combustion of the gases evolved. The heat of the bath is thus raised considerably, and more scrap can be added. At a works at Sheffield, it is stated that two converters made five blows in an average of one hour and fifty-five minutes, the weight of steel for each blow averaging 30 to 32 cwts. For final additions ferro-silicon and ferro-manganese are used. Average tensile tests on a number of 2-inch test-pieces showed 30 tons ultimate strength, 31 per cent. elongation, and 47 per cent. reduction of area.

The Detroit Steel and Spring Works.—E. G. Odelstjerna ‡ states that this works possesses two trains of rolls, eight hammers, one crucible furnace with thirty pots, two Robert-Bessemer converters, each of two tons capacity, and a number of heating and other furnaces. Spring steel and springs of all kinds are made, about 8000 tons a year in all being produced. This is stated to be the only works in the United States at which the Robert converter is successfully employed. Using aluminium and ferro-silicon, castings were produced, which, as far as appearances went, were as good as the best Swedish. Apparently the

* *Stahl und Eisen*, vol. xvi. pp. 704–706.
† *Iron Age*, vol. lvii. pp. 1074–1075.
‡ *Jernkontorets Annaler*, vol. l. pp. 169–404.

phosphorus contents of the metal are not inconsiderable. Castings of many square feet superficies and with flanges a quarter of an inch thick were cast perfectly sharp and without a flaw, although the percentage of carbon was stated to be only 0·10. The springs were made entirely by machinery. The moulds were coated with finely ground pure quartz mixed with wood-oil or varnish; the material for the moulds consisting of a very fine brown quartz sand, which permits the passage of gas very readily. A circular saw is used for cutting-off purposes. A large number of perfect castings weighed only 2 or 3 lbs. Most of the furnaces are heated by petroleum.

FURTHER TREATMENT OF IRON AND STEEL.

The Immel Heating Furnace.—This is a furnace for which a German patent was granted in 1894, and of which forty-five have now been erected. The peculiarity of this furnace is that at one and the same time both puddled bars and sheets may be heated separately by a single firing, and the whole process proceed without the one section of the work interfering with the other. The furnace is continuous in its working, and, with a little practice, neither bars nor sheets show any signs of slagging. The arrangement of the furnace is such that the sheets are heated on the bed of the furnace, while an arch near the fire-bridge, used in earlier furnaces for protecting the sheets from being too strongly heated, is turned into a bed on which the bars are heated. The furnace works cheaply and has a large output; in practice it has more than fulfilled all expectation.*

Electric Welding.—T. Scott-Anderson † describes the Bernardos arc system and the Zerener or deflected arc system of electric welding. Most plants on the former system are worked without batteries, and although the efficiency may be somewhat less, yet the costly upkeep of batteries is avoided, and irregularity in the power used may be obviated by arranging two or three welding tables on one circuit. A number of examples of the work done by this process are then given, and amongst these are repairs to various parts of rolling-mills. For instance, one is of the roughing-rolls for a bar-mill, which under normal conditions works with heavy draughts on hard steel, and by which the wobbler end had been worn, until the coupling-box turned round without driving the roll, thus rendering the roll useless. The roll, which weighs over 50 cwts., was taken out and the worn portions electrically welded up again to original size. The whole operation of taking out, welding, and putting in place again, only necessitated the mill standing for twenty-four hours.

* *Stahl und Eisen*, vol. xvi. p. 666, with one illustration.

† *Transactions of the Federated Institution of Mining Engineers*, vol. xi. pp. 40–54.

The welded roll has now been running for about twelve months, and, although the wobbler is again wearing out, it is satisfactory to know that when it is again worn so that the coupling-box refuses to drive, the welding can be repeated again and again if necessary.

If desired, the dynamo may give current for lighting at night and welding by day. A generator giving 250 to 350 amperes at 85 volts preferably is very suitable, and at this pressure the work may be handled with impunity. The skin and the eyes especially must be well protected from the light of the arc, as results akin to severe sunburns are produced. In order to produce sound welds, the carbons should be uncoppered, hard, and uniform, and must burn with little or no dust deposits. When building up, the same quality of metal should be used, slag should be removed, and the work should be annealed by carefully withdrawing the arc.

The table given below shows the average results of tests of hand and electrically welded bars of different qualities of iron, the upper figures in each double line being for the hand welds :—

Material and Brand.	Nominal Size.	Ultimate Stress Per Square Inch.	Contraction of Area at Fracture.	Extension in 10 Inches.	Ratio of Weld to Solid.	Figure of Merit. Ultimate Stress Multiplied by Contraction of Area at Fracture.
	Inches.	Tons.	Per Cent.	Per Cent.	Per Cent.	
Iron, Low Moor . .	$2 \times \frac{3}{16}$	20·3	15·2	7·3	77·9	308
,, ,, . .	,,	21·1	17·3	7·3	81·1	365
,, ,, . .	$2 \times \frac{5}{16}$	21·5	22·3	11·3	90·7	479
,, ,, . .	,,	21·8	20·7	9·7	91·8	451
Iron, Netherton best	$2 \times \frac{1}{4}$	18·4	10·1	3·4	84·4	185
,, ,, ,,	,,	20·1	10·8	4·5	92·0	217
Steel, Parkgate . .	$2 \times \frac{1}{8}$	20·9	9·3	1·9	69·1	194
,, ,, . .	,,	22·3	18·4	3·8	73·6	410
,, ,, . .	$2 \times \frac{1}{2}$	20·4	15·9	8·1	82·3	324
,, ,, . .	,,	21·0	15·4	7·3	86·4	323

The mean of the electrically heated welds was 18·5 per cent. better in figure of merit than the mean of the hand-made welds.

Where a less intensely concentrated heat is required, as in making seam and lap welds, the Bernardos process is not successful, but the Zerener method may be used with advantage. The arc in this process is formed between two carbons, as in the ordinary arc lamp, but on each side are mounted the two poles of an electro-magnet excited by a part of

the same current. This causes the arc to spread out like a blowpipe flame, which can then be directed on the work. The appliances are made in various sizes, the smallest taking 27 amperes at 70 volts, or about three horse-power, and this size is manipulated entirely by hand. The chief application of this process in welding up to the present time has been in seam welds on sheets or plates up to ½-inch thick.

S. Maccarthy * deals with the manufacture of steam pipes and fittings, and with the applications of the Bernardos system of arc welding. After briefly referring to the replacement of copper by iron, and then by steel, in boiler tubes, the author briefly describes the methods of roll-welding and of gas-welding. The longitudinal seams are not often welded by electricity, as there is no saving in cost, speed, or efficiency. The Bernardos process, however, plays an important part in the manufacture and attachment of flanges, branches, bends, and tee-pieces, and has been in constant use for five years near Halesowen. Low-tension continuous current dynamos supply Bernardos accumulators, and the current from both is used in the welders. The accumulators may be dispensed with, but it is found more economical to use them. The plant is run on the parallel system, and between the terminals of the dynamos or battery as many welding arcs can be connected as desired. Every welder can vary his own current independent of the others. A long arc should be used, as the heat is more evenly distributed, and strains are not set up to the same extent. In working, the carbon pencil is used to cut out any portions that have to be removed, and then in melting on to the junction small pieces of steel.

An illustration is published † of a machine devised by H. Lemp for the electric welding of wheels. The lower part of the machine contains the transformers, and an upper crosshead carries a hydraulic ram, by which pressure is applied to complete the welds. The method of using this machine for the rims, hubs, and spokes of wheels is described.

Steel Castings.—H. Wedding ‡ describes the manufacture and use of ingot-metal castings. Touching on this subject historically, he refers to Huntsman's discovery of the crucible steel process, and then to Krupp's elaboration of this in the present century. The Bessemer and open-hearth processes are also touched upon. He draws a sharp distinction between ordinary castings made of cast iron (*Gusswaaren*) and cast-

* Paper read before the Institution of Mechanical Engineers.

† *Iron Age*, vol. lviii. pp. 105–106.

‡ Paper read before the Verein für Eisenbahnkunde, December 21, 1895, with illustrations.

ings made of ingot metal (*Flusswaaren*), and between the latter and ingots. He deals first with the furnaces used in the manufacture of ingot iron, and with the materials used in its manufacture, and then passes to a consideration of its physical and chemical properties. The chemical composition of the metal, he shows, is very different according to the subsequent use that is to be made of the metal. Thus for bells the composition is usually 0·3 of carbon, 0·35 of silicon, and 0·8 of manganese; for machine parts, 0·5 of carbon, 0·2 of silicon, and 0·5 of manganese; for larger castings the metal usually contains 0·8 of carbon, 0·25 of silicon, 0·6 of manganese; while for rolls the metal used will contain some 1·1 per cent. of carbon, 0·3 of silicon, and 0·7 of manganese. The author points out that the smaller the castings, the lower is the percentage of carbon in the metal used. When, however, strength and the power of resistance to wear are important factors, then the metal used must be higher in carbon than would otherwise be necessary. The author next deals with the tensile strength of the metal used in ingot-metal castings, and he points out that occasionally castings show a tensile strength of 40 tons per square inch, or even more, and that it is possible to produce castings of almost any desired size. The author next deals in detail with the moulds used in making such castings, and with the casting process itself. The subsequent treatment and utilisation of the castings are also dealt with. Here again he draws a comparison between the casting of pig iron and that of ingot metal, showing the differences that exist in the two cases, and he gives illustrations of the uses to which castings of different chemical compositions and physical properties can be put.

Steel Tubes.—H. K. Landis * deals with the manufacture of steel tubing for bicycles and for other purposes where great strength combined with lightness is required. Welded tubes gave way to Mannesmann tubes and to cold-drawn seamless tubing. Greater strength was obtained by increasing the carbon percentage, and now 0·40 per cent. is about the limit. One works at Hartford, however, makes tubes from steel containing 0·50 per cent. of carbon, and also from nickel steel, with tensile strengths of 100,000 and 200,000 lbs. per square inch respectively. The steel is received in the form of sheets 13 by 26 inches, and 0·110 inch in thickness. The composition is as follows:—

	Ni.	C.	P.	Mn.	S.
Nickel steel . . .	5·00	0·25	0·03	0·60	0·03
High-carbon steel . .	...	0·45 to 0·50	0·02	0·15 to 0·30	0·03

* *American Manufacturer*, vol. lix. p. 405.

Discs, cut out by a 12½-inch punch, are reduced by three cupping machines to a cylinder 2 inches in diameter and 2 feet in length. The ends are trimmed, and the tube is then further drawn down with frequent annealing. Oil is used as a lubricant.

Pipe-Making.—A description has been published * of a primitive pipe-making establishment installed 8000 feet up in the Rocky Mountains. In order to avoid the expense of transporting the wrought pipe, a small pair of bending rolls had been procured, and these, with a portable forge, constituted the equipment. Under a shed by the mountain-side three men were turning out length after length of riveted sheet-iron pipe on the spot where it was to be used, and the pipe-line was being constructed 500 feet up the mountain, bringing down 200 horse-power from the stream to the mine below.

Wire Ropes.—F. H. Hopkins † states that wire rope in Canada is chiefly made by two manufacturers. The various lays of rope are described, and, amongst other applications, wire ropeways are shortly discussed.

Structural Steel Fly-Wheels.—According to T. E. Murray,‡ the too frequent bursting of cast-iron fly-wheels of heavy type and large diameter, owing to the increased speeds that are recklessly common, led him to devise a structural fly-wheel of open-hearth steel to replace a broken one of cast iron. The total weight of this wheel is 29 tons, approximately distributed thus: rim, 16 tons; disc-web, 8½ tons; hub, 4½ tons. The factor of safety is estimated at nearly 26, assuming that the weakest part of the wheel lies in the outer layer of rim-plates, which must obviously give way before the remaining parts.

Iron Tunnels.—W. O. Leitch § describes the general methods of construction of iron tunnels driven in cities, far below all obstruction, and from an operating base, so as to involve the least interference with street traffic. The cost of such tunnels may be taken at 30s. per cubic yard, and the life of an iron tunnel should not be any less than that of a brick one.

* *Cassier's Magazine*, vol. x. p. 306.
† *Journal of the Canadian Mining Institute*, vol. i. pp. 185–191.
‡ *The Electrical World*, New York, vol. xxvii. p. 680.
§ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxv. pp. 377–396.

High Carbon Steel Rails for Tramways.—In a paper recently read before the New York Street Railway Convention, C. L. Allen * states that rails of hard steel, the analysis of which showed a greater percentage of carbon than the standard specification of rail-steel, have been advocated by some of the steam railway systems for some years, and their use has been a success in every way. The most notable instance of high-carbon rails, he stated, is on the New York Central Railroad on the Hudson River Division, near Spuyten Duyvil. These rails have been subject to as heavy traffic as any rails laid in America. They have been under traffic for nearly six years, and up to this time, he believed, none had broken. When these rails were first delivered by the makers, so certain were they that the rails would become broken under traffic, that due warning was given the railroad company by the makers that they would not be responsible for the damage which would most certainly occur through breakage. Early this year the author consulted with an expert in regard to the wearing qualities of high-carbon rails as compared with that of rails known as standard Bessemer rail-steel, and their judgment was that high-carbon rails will give from 40 to 60 per cent. greater life than rails of standard Bessemer steel. When railways began to ask for steel rails the composition of which called for high carbon, an extra price, from two to four dollars per ton, was asked by the rail-makers; but to-day these rails are obtainable for the same price as those of standard rail-steel specifications. In Syracuse this year, rails 60 feet in length, 9 inches in height, with the half-groove section, are being laid. The joint is the ribbed or corrugated 12-bolt, 36-inch joint. The contract with rail-makers calls for rails the composition of which is as follows: carbon from 0·53 to 0·63 per cent., phosphorus not to exceed 0·095 per cent., sulphur not to exceed 0·07 per cent., manganese 0·80 to 1·09 per cent., silicon 0·10 to 0·12 per cent. Five miles of track with rail of this specification have been laid, and it is hoped this year to lay twenty miles. The author has noticed that the wear on the head of the rail by car-wheels in the course of a month does not make any impression other than brightening it at this point, while in rails of standard specification under the traffic of two weeks the metal in the head of the rail rolls to the outside of the head to a very perceptible degree. The fact that there is a longer life to rails of hard steel will appeal to every railway and tramway man as an economy which cannot be sacrificed.

* *Electrician*, vol. xxxvii. p. 786.

Railway Axles.—A committee of the National Railroad Master Blacksmiths' Association recommend * that axles for railway vehicles should be made from scrap iron mixed with about half its weight of muck bar. The piles are to be made of cleaned scrap cut into 18-inch lengths, placed in layers at an angle with each other. No steel should be present.

Steel Framing for Railway Vehicles.—A recently published report † of a committee of the Master Car-Builders Association deals chiefly with recommendations as to the structural form of the members used in steel framing for railway vehicles, and to the questions of riveting and bolting the parts together.

Ornamental Ironwork.—An illustrated historical description has been published ‡ of wrought and cast ironwork.

A description has been published § of the works at Chicago devoted to the manufacture of ornamented sheet metal. The building covers 50 by 100 feet, and contains four stories. The basement contains boilers, engines, and store-rooms for raw material, consisting of tin and black plates. The second floor contains machines for lacquering, varnishing, and painting, with drying ovens. Embossing machinery is placed on the next floor.

Damascus Gun-Barrels.—The making of barrels for sporting guns in the valley of the Vesdre, in the province of Liége, is a very interesting mechanical operation. These barrels are called "Damascus," because the damascene appearance of the metal resembles that of the celebrated Damascus sword-blades, famous for their fine quality. The damascus gun-barrels herein described are made entirely by hand. The United States consul at Liége has described this manufacture in one of his reports, from which the following abstract has been made:—

The steel is imported from Westphalia; the iron is manufactured at Couvin; the coal for the numerous forges is obtained from the mines of the Highlands of the Herve, situated in the vicinity of this industry, which furnish coal especially fitted for this work. The factories receive their motive power from the river Vesdre. The industry is said to be on the increase. Some years ago forges and workshops were entirely

* *American Manufacturer*, vol. lix. pp. 405–406.
† *Iron Age*, vol. lvii. pp. 1466–1467.
‡ *Illustrated Carpenter and Builder*, August 21, 1896.
§ *Iron Age*, vol. lviii. p. 623.

engaged in making iron barrels, and there were but few barrel-makers who produced tubes or barrels known as twist barrels, called by the French *canon tordu*, or *tors*, from *tordre*, to twist or contort. The ingot for the production of the curled damascus, which is the favourite design for fine guns, is composed of about thirty sheets of iron and steel, each having the thickness of four millimetres and a breadth of one hundred and twenty millimetres, which form a square mass about fifty centimetres long, and are enveloped in a box of common thin sheet iron or bound by small wires at each end. The package thus prepared is put into an oven and welded together at the lowest possible temperature. Too great a heat destroys the metal and yields a burned damascus, showing a small, if any, design. Each barrel receives one hundred and fifty welding heats while being forged, making three hundred heats for a double barrel.

If one of these welding heats is unsuccessful, the barrel may be a failure, either by the alteration of the damascene appearance or by a trace of the smallest imperfection in welding. Swedish iron is not used in forming curled damascus; only refined charcoal iron of Belgium, which gives a greater contrasting hue to the steel, and can be welded at a lower heat. After the ingot is welded, it is rolled into small square rods of seven to nine millimetres, according to the design of the damascus desired.

The rods are then drawn into ribbons by the smiths. The manipulation of these ribbons at high temperature is such that in a length of one metre two hundred twists are shown. Coke iron will not answer for this fine work, for which charcoal iron is used exclusively, though an inferior quality of damascus can be made from coke iron. The twisting increases in pitch towards the thinner part of the barrel, which is first formed by winding the ribbons on a mandrel and welding the coils together at the edges. The barrels are then bored out, straightened, ground to the proper thickness, and polished. The joining of the barrels for double-barrelled guns is a process requiring great care, as the value of the gun largely depends upon the accuracy with which this part of the process is executed. Each barrel is proved by a shooting test at the manufactory before it is placed on sale. It is said that the annual production of these barrels is three hundred thousand, and that they are chiefly exported to England and the United States.*

The Manufacture of Dynamos.—E. Schulz † considers the ques-

* *Engineering Magazine*, vol. xii. pp. 161-162.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 817-820, with six illustrations.

tion whether steel castings or cast iron should be used in the manufacture of dynamos. Considering the question electrically, and dealing with past experience, he asks the question whether steel castings possess such marked advantages for this purpose over ordinary castings as to justify their use on so extended a scale. He shows that cast iron is preferable in some cases, while for other forms of machine the use of steel is preferable to that of cast iron.

The Manufacture of Needles at Schwabach.—An account is published of a visit to the needle factory of Messrs. Staedtler & Uhl at Schwabach. The manufacture of needles was commenced at Schwabach in 1633, and at the end of a century one hundred workshops were in operation. In 1787 the annual production of needles had risen to 200,000,000, and the maximum out-turn on the old system was reached in 1814, when, with 1600 workpeople employed, 300,000,000 needles were produced.

An outline sketch is given of the manufacture as now carried on at these works.* The wire is first cut into two-needle lengths by a machine cutting daily from 400,000 to 450,000 of these. They are packeted, annealed, freed from scale by rolling backwards and forwards under pressure, and pointed by a machine that can point at both ends about 150,000 double blanks daily, whereas one skilled workman was scarcely able to point one-tenth this number. Then in another machine the shape of the eye-heads is formed, while in another the eyes are produced; and finally, after further cleaning, the two needle-heads are separated and the rough surfaces at the fracture smoothed off. The needles are then oil-hardened, subsequently tempered, and finally polished.

Schulte-Hemmis Shell Process.—The manufacture of hollow projectiles, and in especial the Schulte-Hemmis process, is described by J. Castner.† This latter process aims at producing from malleable metals hollow bodies of an internal shape so accurate that no further subsequent treatment is necessary. This may be effected in various ways, but is mainly done by pressure. Shells of various forms are described.

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 733–734; compare also *Journal of the Iron and Steel Institute*, 1895, No. II. p. 536.

† *Stahl und Eisen*, vol. xvi. pp. 500–504, with four illustrations.

PHYSICAL PROPERTIES.

The Microstructure and Hardening of Steel.—A. Sauveur * describes at some length the changes of microstructure which occur during slow cooling in steels containing various amounts of carbon; and, secondly, examines what bearing, if any, such structural changes as occur at the critical points have upon the current theories of hardening. After a brief account of the critical points, and of the methods of developing the microstructure of polished sections, the various constituents—ferrite, cementite, pearlite, and martensite—are described at length, and the proportions of these in different kinds of steel are given. Six samples of steel containing 0·09, 0·21, 0·35, 0·80, 1·20, and 2·50 per cent. of carbon were quenched after slow cooling at various temperatures above, between, and below the critical points. The samples were then polished, and the area occupied by each constituent was determined by planimeter measurements on the magnified sections. The results for each kind are separately dealt with; but the table given below is abridged from one given by the author, for one sample containing 0·21 per cent. of carbon:—

Quenching Temperatures. Degrees Centigrade.	Positions of Quenching Temperatures.	Microstructural Composition, Per Cent.		
		Martensite.	Ferrite.	Pearlite.
880–733	Above Ar_2	100	0·0	0·0
714	Beginning of Ar_2	97·20	2·80	0·0
713	,, ,,	86·00	14·00	0·0
698	Middle of Ar_2	70·20	29·80	0·0
652	Between Ar_2 and Ar_1	35·20	64·80	0·0
626	,, ,,	31·50	68·50	0·0
620	Beginning of Ar_1	30·00	68·40	1·60
600	End of Ar_1	4·00	78·50	17·50
559	,, ,,	2·00	75·80	22·20
575	Below Ar_1	0·0	78·90	21·10
200	,,	0·0	76·40	23·60

* *Transactions of the American Institute of Mining Engineers*; Colorado Meeting, 1896 (advance proof).

All the experiments show that each critical point is accompanied by a structural change which begins and ends with it. In the ranges of temperature where there is no critical point, no change in the micro-structural composition is found. The changes at the upper retardations Ar_3 and Ar_2 are merely structural, and consist in the liberation of a certain amount of ferrite which above those points was included in the martensite. The change at Ar_1, or at the composite point $Ar_{3,2,1}$, consists in the disappearance of martensite and the appearance of pearlite. Above Ar_3, 0·12 part of carbon combines with 99·88 parts of iron. The martensite cannot absorb more ferrite, and if the steel contains less than 0·12 per cent. of carbon there is an excess of iron which remains unabsorbed as structural free ferrite. Between Ar_3 and Ar_2, 0·25 of carbon and 99·75 of iron are found, and in this range of temperature martensite cannot assimilate more ferrite, of which the excess remains structurally free. Between Ar_2 and Ar_1, the amount of ferrite which can unite with carbon to form martensite is further lowered, being 0·50 carbon to 99·50 of iron, and the excess is again unabsorbed. There is thus what might be called a saturation point of carbon for iron, and, on heating, each retardation raises the saturation point, causing a new structural arrangement.

The author then proceeds to discuss the application of various theories to the phenomena of hardening, and he gives in tabular form the explanations offered for the results of each stage. He himself does not wish to advance any new theory, but his position as stated in this table is as follows: Above Ar_3, very mild steel made up of martensite and ferrite—cause of evolution of heat at Ar_3, separation of a certain amount of ferrite previously included in the martensite; between Ar_3 and Ar_2, soft and medium hard steel made up of martensite and ferrite—cause of evolution of heat at Ar_2, separation of an additional amount of ferrite from the martensite; between Ar_2 and Ar_1, soft steel martensite and ferrite, medium hard steel martensite, hard steel martensite and ferrite—cause of evolution of heat at Ar_1, disappearance of martensite and appearance of pearlite; below Ar_1, soft steel pearlite and ferrite, hard steel pearlite and cementite—cause of hardening, retention of martensite by sudden cooling.

The Diffusion of Metals.—In the "Bakerian" lecture of the Royal Society,* Professor W. C. Roberts-Austen shows that metals are capable of diffusing into each other, not only when one is in a state of fusion,

* *Philosophical Transactions*, vol. clxxxvii., pp. 383–415, with two plates.

but when both are solid. If clean surfaces of lead and gold are held together *in vacuo* at a temperature of only 40° C. for four days, they will unite firmly, and can be separated only by a force equal to one-third of the breaking strain of lead itself; and gold placed at the bottom of a cylinder of lead, 70 millimetres long, thus united with it, will have diffused to the top in notable quantities at the end of three days.

The Magnetic Properties of Iron.—At a meeting of the Institution of Civil Engineers, two communications* dealing with the magnetic properties of iron and steel were considered.

In the first paper J. A. Ewing referred to the practical importance which now attached to the magnetic testing of iron and steel in relation to the manufacture of dynamos and transformers. From being a mere laboratory experiment interesting only to students of physics, it had passed into the rank of an engineering operation. Ironmakers now supplied material greatly superior, from the magnetic point of view, to that which could be obtained even two or three years ago. In dynamo construction the introduction of permeable steel castings for the field magnets had given greater latitude as to form without loss of efficiency, the best steel castings being indeed somewhat better magnetically than most forged iron. In stampings of sheet metal for transformers the main consideration was absence of hysteresis, and so great had been the advance in this respect that iron was now readily obtainable with only half the amount of hysteresis which was considered possible a few years ago. This had brought about a notable increase in the efficiency of alternate-current distribution by reducing the large element of loss which occurred through the hysteresis of transformer cores during the hours of light load as well as of heavy load. The author recalled the conventions according to which the magnetic quality of iron was expressed. The most usual test was one to determine the relation of the magnetic induction to the magnetising force, the ratio of B to H being the permeability. To enable H to be determined with accuracy, the specimen was arranged as a closed ring, or as an ellipsoid, or as a bar or bars rendered practically endless by the use of a yoke. Ballistic methods of testing were described, and it was shown how in the use of a yoke the proper correction might be experimentally found, to deduce the true magnetising force by allowing for the magnetic resistance of the yoke itself. For this purpose the author used a pair of bars joined by two short yokes at their ends, the yokes being shifted so as to include

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxvi. pp. 185–267.

either the whole length or half the length of the bars in the magnetic circuit. Reference was made to various forms of apparatus designed to measure the magnetic induction by observing the force required to separate surfaces in the magnetised piece, and a form used by the author was described in which a yoke piece was simultaneously drawn away from polar extensions at both ends of the bar. A novel apparatus was shown in detail for measuring permeability by comparing the magnetising force required to produce a given induction with the force required to produce equal induction in a standard bar. This apparatus, which the author terms a magnetic bridge from its analogy to the Wheatstone bridge for the measurement of resistance, reduced the operation of testing to a comparison between the specimen and a bar the magnetic quality of which had been determined once for all by the instrument-maker. The two bars were connected by end yokes, and by varying the number of turns in the magnetising coil on one of them, the yokes were brought to the same magnetic potential. The relative number of turns on the two thus gave the relative magnetising forces required to produce the same induction in both. A simple form of magnetic detector showed when the two yokes were brought to the same potential. The manipulation consisted in varying the number of turns acting on one bar by means of dial switches, while the magnetising current was from time to time reversed. This permeability tester was intended for workshop use, and might take its place alongside of the author's hysteresis tester, which was also described. The methods of directly measuring hysteresis were briefly referred to. A number of representative examples were given of permeability tests of forged wrought iron, forged steel, and cast steel, for dynamo magnets; also of hysteresis tests of transformer plate rolled from Swedish wrought iron and from ingot metal. The results were shown by means of numerical tables and also in curves.

The second paper, on "Magnetic Data of Iron and Steel," was by H. F. Parshall. Magnetic tests of iron and steel might be conducted to determine such properties as permeability, maximum magnetisation, residual magnetism, and permanent magnetism, and the relation they bore to tempering, annealing, internal stresses, composition, and processes of manufacture. The loss of energy through hysteresis might be determined either magnetically by determining the area of the loop formed by plotting the flux densities as ordinates, and magnetic force as abscissæ, or mechanically by suitable power-measuring apparatus. A study of the magnetic results and of the chemical analysis showed a more or less

intimate relationship according to the degree with which the modifying physical conditions might be controlled. In general, a greater degree of purity was an indication of high permeability; but as the different qualities of iron and steel merged into each other by insensible degrees, owing to variations in the processes of manufacture, chemical analysis might be taken only as an approximate indication of the magnetic properties. Carbon was the most important element entering into the composition of commercial iron, and, within the limits that chemical analysis might serve as an indication of the physical structure, the permeability was inversely as the amount of carbon present. The limitation as to the state of physical structure was greatly affected by the state of the carbon, that was, whether free or combined; in cast iron as well as in steel, the effect of graphite was second to that of the carbide, commonly known as fixed or combined carbon.

Beyond a certain degree of purity, as in wrought iron and carbon steels, the treatment as to annealing and tempering became of first importance. The magnetic properties of some of the alloys of iron, nickel, or manganese, were such as to show that the physical structure was the ultimate determining factor. The hysteresis loss was in general inversely as the degree of purity; but in comparatively pure irons it was determined principally by its treatment as to annealing, heating, and mechanical straining.

J. Dewar and J. A. Fleming * have studied the changes produced in magnetised iron and steels by cooling to the temperature of liquid air. The metals investigated were: Knitting-needle steel, (*a*) tempered glass hard, (*b*) medium temper, (*c*) annealed soft; chromium steels containing 0·29, 1·18, 5·44, and 9·18 per cent. of chromium; aluminium steels containing 0·72, 1·16, and 1·60 per cent. of aluminium; nickel steels containing 0·94, 3·82, 7·65, 19·64, and 29 per cent. of nickel; pure nickel silicon steel containing 2·67 per cent. of silicon; soft iron, hard iron, tungsten steels containing 1·75 and 15 per cent. tungsten. Broadly speaking, the results so far obtained are :—

(1) That the sudden cooling to the temperature of liquid air usually permanently decreases the magnetic moment of short magnets made of many varieties of steel, assuming them to have been initially magnetised in a strong field.

(2) This initial decrease is found both in hardened steels having great coercive force, and also in the same steels in a soft or annealed condition, and is especially conspicuous in the case of the 19 per cent. nickel steel.

* *Proceedings of the Royal Society*, vol. lx. pp. 57–71.

(3) In the case of most steels so far examined the effect of cooling magnets made of them to –185° C. is to temporarily increase the magnetic moment after the permanent magnetic condition has been reached.

(4) The exceptions to the above rule so far noted are the nickel steels, with percentages of nickel from 19 to 29 per cent., in which case the magnetic moment is always decreased temporarily by cooling to –185° C. after the permanent magnetic condition has been reached.

(5) It appears from these experiments that one of the best ways of *ageing* a permanent magnet is to dip it into liquid air. It then arrives at a constant condition in which subsequent temperature changes have a definite effect, and in which the sub-permanent magnetism is removed.

In a monograph on the magnetic hysteresis of iron, C. Heinke * observes that two main magnetic properties of iron are of importance in electro-technology—the permeability of the lines of force, and the magnetic molecular friction or hysteresis. As regards the permeability, this offers but little difficulty, but the conditions are less favourable in the case of the hysteresis. In the first place, it would naturally be assumed that there was a direct connection between this and the chemical composition of the iron. This is, indeed, true as regards higher percentages of impurities, but in the case of the softer varieties of iron and steel no such direct connection is evident. Of the elements present in steel, manganese in particular affects unfavourably the permeability and hysteresis, and tungsten is also most remarkable in its action, tungsten magnets being very permanent. In general, it may be stated that, as regards hysteresis, iron is the better the freer it is from foreign elements; but it has been found that even when the chemical composition of two samples of steel is approximately identical the hysteresis may be very different in the two cases. This difference was found to exist, too, in a metal sold by the same English rolling-mill as of the same quality. This showed, it is true, the same permeability throughout, but a difference of more than 70 per cent. existed in the hysteresis. Differences of 20 per cent. are quite common, and it is consequently probable that the hysteresis depends more on the physical properties of the metal than on its chemical composition, and the treatment of the metal during its manufacture exerts a marked influence. In this connection, too, it may be accepted as a rule that the harder is the iron the worse it is as regards hysteresis. It is just this extreme variation in the value of η (hysteresis), that exists in the same brand even, which forms such a prominent evil, and scarcely allows of any average value being accepted for a particular brand of metal.

* *Stahl und Eisen*, vol. xvi. pp. 716–722.

The author deals at length with this subject, and also with Ewing's experiments. He observes that the most complete purification of the metal will be just as little able to eliminate this magnetic friction as it is to eliminate the mechanical friction, but the enormous existing variations in the value of η are capable of being avoided. In conclusion, the author repeats some of the more important of the results of the investigations of Steinmetz, who examined a number of different kinds of iron. For weld iron and iron sheets the value of η varied from 0·002275 to 0·00548, that is to say, more than twice the lower figure. Curiously enough, in cast iron, where great variations were presumably probable, the value of η varies but little, the value of η having been found to vary only between the limits 0·0113 and 0·0158 in the case of eight samples from different works.

The hysteresis of iron and steel in a rotating magnetic field has been investigated by F. G. Baily,* and J. A. Fleming and J. Dewar † have investigated the magnetic permeability and hysteresis of iron at low temperatures.

P. Weiss ‡ writes on the magnetism of crystalline magnetite. He cut some dodecahedra in various directions, and found the greatest residual and the least total magnetisation in the direction of the quaternary axis. The paper is illustrated by some interesting diagrams, showing the distribution of magnetisation in the direction of the field, and perpendicular to it.

Recent Work on Molecular Physics.—R. A. Fessenden § discusses the behaviour of metals which are in everyday use, and attempts to explain this behaviour by certain original theories.

The Influence of Temperature on Tensile Strength.—A. Ledebur ‖ publishes an elaborate monograph on the influence exerted by changes in the temperature on the tensile strength of metals and especially of iron. He deals with the work that has been done in this direction by a number of experimenters, and gives a series of curves illustrating the results obtained. In summarising these he observes that malleable iron at the lowest temperature yet used—80° C.—possesses a

* *Proceedings of the Royal Society*, vol. lx. pp. 182–183.
† *Ibid.*, vol. lx. pp. 81–95.
‡ *Journal de Physique*, October; *Electrician*, vol. xxxvii. p. 786.
§ *Journal of the Franklin Institute*, vol. cxlii. pp. 187–216.
‖ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 565–573, 596–603, 635–638, with twenty-two figures.

relatively high resistance to steady stress. The strength of the metal decreases until the temperature of from 60° to 100° is reached, though in the case of the experiments of Howard and Rudeloff the limit of temperature appears to be at 0° or but slightly above this. This temperature limit passed, the strength of the metal increases rapidly, and at 200° to 300° it is stronger by 4·4 to 6·4 tons than it is at ordinary temperature, and from 1·9 to 3·2 tons stronger than it is at 80°. Beyond this point the strength again diminishes more and more until the metal finally softens. At those temperatures at which the strength is greatest the metal is most brittle, and percussion is especially dangerous to it. Weld iron and ingot iron behave very much alike. Not only is the metal at temperatures of 200° to 300° or rather more, especially affected by percussion, but its bending capacity is also greatly diminished. Increasing cold seems only to diminish the bending capacity of iron when the metal has previously received some injury. But little has been done with regard to cast iron; but it, too, appears to become more brittle at very low temperatures, though it changes less than malleable iron does up to a red heat, when its strength diminishes rapidly.

The Transparency of Iron.—G. Le Bon * has experimented on the transparency of metals to chemically active light rays; for rays, that is, which are not rare ones like those of Röntgen, but which occur in ordinary light. He finds that they will penetrate even the heavy metals, and are capable of producing photographs. Iron and copper are particularly transparent to them. He suggests the name of *lumière noire* (black light) for these rays, which are not perceptible to the ordinary eye, and he thinks that a slight change in the formation of the eye would enable even the thickest wall to be readily seen through.

Testing with the Röntgen Rays.—Haedicke † observes that soon after the publication of the peculiar properties of the Röntgen rays it was suggested that they might be made of use in determining the properties of metals, and he himself desired to examine a well-arranged collection of samples of steel containing from 0·6 to 1·5 per cent. of carbon, but was assured that the rays could not penetrate sheets of 4 millimetres in thickness. Now, however, the author has obtained

* *Comptes Rendus de l'Académie des Sciences*, 1896, p. 188; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 257–258.

† *Stahl und Eisen*, vol. xvi. pp. 657–660, with sheet of illustrations.

such photographs. He describes the method he adopted, and gives a number of the results he obtained. Iron proved quite diaphanous when in a thin sheet, but owing to accidental differences in thickness he was able to obtain photographs resembling the well-known porcelain transparencies. Other experiments tended to prove the truth of the law that the transparency of a substance to the rays decreases on the whole as the specific gravity increases. A very interesting series of experiments which the author also describes shows that the light rays emitted from a piece of red-hot iron act similarly to the Röntgen rays, and he showed further by the use of an alum cell that it was not the heat rays which caused this result.

Determining the Hardness of Steel.—A. Föppl * observes that he was asked to determine the relative hardness of two plates of steel intended for safe manufacture. These were each about 6 millimetres in thickness. He first endeavoured to obtain a comparison by a determination of the yield point, for it is evident, he adds, that the metal must offer a greater resistance to mechanical action the greater is the tension it can withstand without lasting deformation. It is rarely possible, however, to ascertain this with a sufficient degree of accuracy, and the results he obtained for the two metals were too much in accord to enable him to utilise them for the purpose he had in view. He then tried the method proposed by Hertz. From each plate of steel he caused two pieces to be made about 15 millimetres in diameter and 25 in length. On one of their wider sides these pieces were made cylindrical in shape and well polished. The diameter of the cylindrical face was in each case 20 millimetres. The test-pieces to be compared were then placed on each other with their cylindrical faces cross-wise, so that they only touched at one point. They were then pressed together with a gradually increasing pressure until a lasting impression had been made. The harder is a body the greater must be the force required to produce this effect, and this method can therefore be used as a means of determining the relative hardness. The experiments were perfectly successful. In the case of the harder steel a lasting impression just became visible at a pressure of 3½ tons; in the softer metal this was noted at only 0·35 ton, while at 0·7 ton a flattening-off, 2·7 millimetres in diameter, resulted. The author observes that this method possesses many advantages, and he gives other instances of its use in connection with cast iron and with copper.

* *Centralblatt für Bauverwaltung*, 1896, p. 199; *Stahl und Eisen*, vol. xvi. p. 601.

The Nature of Wrought Iron and Steel.—W. F. Durfee * discusses the conditions which cause wrought iron to be fibrous, and steel low in carbon to be crystalline. A number of analyses of metal ranging from a trace up to 1·645 per cent. of carbon are given to show the gradations in this element, and to demonstrate that wrought iron may contain more carbon than some of the mild steels. The manufacture of wrought iron is then described, and the behaviour of the cinder during the working is discussed as regards its effect in separating the pure iron crystals and causing them to be drawn out into fibres. The question of so-called crystallisation is also dealt with, the appearance being described as solely due to sudden fracture. Attention is then turned to the manufacture of steel in which greater homogeneity is produced by fusion. In spite of the absence of cinder, there is a great lack of homogeneity owing to blow-holes, and the behaviour and effect of these is dealt with at some length. Fluid compression is discussed, and its value discounted to a considerable extent. Cavities of other kinds, such as those produced by the stresses set up on sudden heating, are also referred to.

The Mechanical Properties of Steel.—Baron Jüptner von Jonstorff † has discussed at some length the relations which exist between the chemical and physical, or rather, as A. Ledebur ‡ points out, between the chemical and mechanical properties of steel. Jüptner, he observes, starts with the assumption that the influence of an atom of one element on the metal is identical with that of an atom of another element; thus 12 parts by weight of carbon would exert the same influence on the tensile strength of steel as 28 of silicon or 54·8 of manganese. This ratio put in a simpler form is 3 carbon = 7 silicon = 14 manganese. Every 3 per cent. of carbon or 7 of silicon or 14 of manganese are stated as increasing the tensile strength of iron at the rate of 20 tons per square centimetre. If the tensile strength of pure iron is assumed to be A, and its contents in foreign elements be expressed in thousandths instead of hundredths, one obtains for the tensile strength of iron, expressed in tons per square centimetre, the expression—

$$B_z = A + \frac{2}{3}C + \frac{2}{7}Si + \frac{2}{14}Mn.$$

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* *Journal of the Franklin Institute*, vol. cxlii. pp. 110–148.

† *Beziehungen zwischen Zerreissfestigkeit und chemischer Zusammensetzung von Eisen und Stahl*; 1895; and *Beziehungen zwischen der chemischen Zusammensetzung und den physikalischen Eigenschaften von Eisen und Stahl*, Leipzig, 1896.

‡ *Stahl und Eisen*, vol. xvi. pp. 348–351.

An iron with 0·54 per cent. of carbon, 0·308 of silicon, and 0·417 of manganese would consequently have the tensile strength—

$$A+\frac{2}{3}\cdot 5{\cdot}40+\frac{2}{7}\cdot 3{\cdot}08+\frac{1}{7}\cdot 4{\cdot}17 \text{ tons.}$$

Or if $A=2{\cdot}50$, then 7·58 tons.

In considering this question it must be remembered that the different forms of carbon may exert different degrees of influence, though the differences to which this leads cease to be of importance if the percentage of total carbon is small, and if the metal was cooled down in the ordinary way. Again, the influence of an element, as Hadfield has shown in the case of chromium, may vary greatly according to the presence or absence of other elements. In the absence of carbon, chromium exerts but little influence; while if carbon is present, its influence is considerable. The same may be said, too, of phosphorus.

In the first of Jüptner's memoirs, Ledebur observes, by means of the formula just given, and making $A=2{\cdot}50$ tons, the actual tensile strengths of 393 samples of ingot iron and steel are compared with those obtained theoretically by means of the formula. In another formula elaborated by Webster, the value attributed to phosphorus is made to vary according to the percentage of phosphorus that is present, and that for manganese is also a variable one according to its percentage. In the case of only a few of Jüptner's examples, however, is a comparison possible between the two formulæ, as Webster's relates only to basic steel, ingot metal free from silicon, and with not more than 0·19 per cent. of carbon, while Jüptner deals mainly with steels of high carbon—up to 0·7 per cent.—and, as a rule, with not inconsiderable quantities of silicon—up to 0·5 per cent. Jüptner does not take into consideration the influence exerted by any phosphorus that may be present, and this, according to Webster, raises the tensile strength by 0·38 to 0·63 ton per square inch for every 0·01 per cent. of phosphorus.

In Jüptner's examples the difference between the actual results and those calculated by means of his formula vary as follows:—

	Kg. per square millimetre.
In 57·13 per cent. of all the examples, between	1–3
„ 29·69 „ „ „ „	3–5
„ 9·90 „ „ „ „	5–6
„ 3·26 „ „ „ over	6

Of the 57·13 per cent., 17·18 per cent. had a difference not exceeding 1 kilogramme per square millimetre (0·63 ton per square inch). In the case of Webster's formula, 89·9 per cent of his examples showed

differences not exceeding 2·8 kilogrammes, while in 28·9 per cent. it did not exceed 0·7 kilogramme.

Jüptner next considers a number of steel rails, analyses of which, with the results of tensile tests, have been given by Tetmajer. Satisfactory agreement was obtained when the value for carbon was taken as follows:—

For iron with from 0·1 to 0·6 per cent. of carbon	.	A=2·3 tons.
,, ,, 0·6 to 0·8 ,, ,,	.	A=1·8 ,,
,, ,, 0·8 to 1·13 ,, ,,	.	A=1·2 ,,

From this variation in the values Jüptner considers there may be deduced the extent of the mechanical treatment to which the iron had been subjected, but to this Ledebur takes exception.

In his second memoir, Jüptner takes into consideration the reduction of area resulting after the tensile test, and gives the formula for this $q = B - f$ (C, Si, Mn), in which B is the reduction of area in the case of pure iron, the value of which, however, is dependent on the mechanical treatment to which the metal had been previously subjected. B was found to have as an average the value of 60 per cent., and for the diminution of B by each 0·3 per cent. of carbon, 0·7 of silicon, or 1·4 of manganese, 14 per cent. For a steel with 0·542 per cent. of carbon, 0·260 of silicon, and 0·281 of manganese, the reduction of area calculated as above would be—

$$q = 60 - 14\left(\frac{0·542}{0·3} + \frac{0·260}{0·7} + \frac{0·281}{1·4}\right) = 26·7 \text{ per cent.}$$

While in many cases this formula gives satisfactory results, in others this is not the case; and Jüptner concludes that (1) the tensile strength and the reduction of area are dependent both on the chemical composition of the metal and on the mechanical treatment to which it had been subjected; (2) for metals which have been similarly treated the tensile strength and reduction of area may be calculated fairly approximately; (3) inversely the degree of mechanical treatment may be deduced; (4) the value of A and B may be used to judge of the qualities of the metal; and (5) these same values may be made of use generally in connection with the question of faulty material.

Ledebur discusses each of these deductions. He agrees generally with the first, and also in the main with the remainder, with some qualifications. He draws attention also to some other points.

Initial Strains in a Steel Forging Cooled from the Interior.—An extensive series of experiments have been made, and the results dis-

cussed by Captain F. E. Hobbs and Captain R. Birnie,* to determine the initial strains in a hollow steel forging cooled from the interior. The forging corresponded to a 3·2 inch field-gun. Slices were cut from near the breech and the muzzle, and from two intermediate points, and from these slices successive rings were cut off and the deformations noted. The rings were annealed, shrunk together, and otherwise tested. Full details of the numerical results are given in a number of tables and also in graphic form. It is shown that there is close agreement between the calculated and observed figures for the stresses, and this is evidence of the uniformity of results obtained by treatment. The strains engendered by the simple interior cooling were too severe, but they were remedied by annealing, and thus a gun could be made similar to one built up by shrinking on successive tubes.

Influence of the Size of Test-pieces.—P. Kreuzpointner † shows how the size of test-pieces affects the results obtained for elastic limit and tensile strength. In small or badly-shaped pieces the metal cannot flow freely under the load, and fictitious values are thus obtained. The variation for pieces 1½ inch by ½ inch in section was as follows:—

Length of section, inches	1	2	4	6	8
Tensile strength, lbs. per square inch . . .	72,000	65,100	62,700	60,300	59,000

Similar tests for elongation showed:—

Length of specimen, inches . .	1	2	4	6	8
Elongation per cent. on pieces of section—					
2½ by ½ inch	67	50	36	30	27
1½ by ½ inch	61	43	31	26	24
½ by ½ inch	55	40	30	26	23

A. Martens ‡ discusses the influence of the form of the test-piece on the results of compression tests. He cites the older experiments of Bauschinger, and his own showing that bodies geometrically the same, of the same material, under similar conditions exhibit analogous geometrical changes of form.

H. B. Seaman § has published a summary of the recommendations of the committee of the American Society of Civil Engineers, as given in their general report.

* *Notes on the Construction of Ordnance*, No. 70, Washington, 1896.
† *Iron Age*, vol. lviii. pp. 168–169.
‡ *Mittheilungen aus den königl. technischen Versuchsanstalt*, vol. xiv. p. 133.
§ *Engineering News*, vol. xxxvi. p. 38.

Testing Machines.—A photographic reproduction of a Riehlé 100-ton testing machine has been published.* It stands 8 feet 10 inches high, and occupies a ground space of 3 feet 7 inches by 9 feet 9 inches, and weighs 12,000 lbs. Specimens up to 30 inches long can be tested in tensile tests; transverse tests can be made on pieces up to 36 inches long and 12 inches in width, and compression tests on pieces 24 inches long. The machine is of the multiple lever type, with three horizontal levers. The upper crosshead is movable, and is driven by a pair of screws which have ball bearings to take the thrust. The Riehlé Gray weighing appliance is attached.

It has been considered † that the anvil in drop testing machines should be as nearly as possible absolutely rigid, so that all the energy might be expended on the piece being tested; but the amount of rigidity obtained in different machines is a variable quantity, depending upon the weight of the anvil and the condition of the ground. F. D. Casanave,‡ of the Pennsylvania Railroad Company, prefers, however, to support the anvil on springs, so as to offer a constant resistance. In the machine constructed to test railway axles the anvil consists of a block of iron about 4 by 5 by 2 feet, weighing 17,500 lbs., and supported on twelve double coil springs which are $9\frac{1}{8}$ inches high when open, and are compressed to 7 inches under 80,000 lbs. The tup weighs 1640 lbs., and has a maximum fall of 43 feet. It is expected that by using these spring supports more comparable results will be obtained.

Testing Cast Iron.—W. J. Keep § again describes the results of his methods of testing cast iron, and shows with the aid of diagrams how to find the strength of test bars of different sizes from the figures obtained from smaller or larger pieces. Shrinkage is also plotted in relation to silicon, and the deflection, set, and chill are also briefly discussed. A résumé of the effect of silicon and carbon on physical quality is then given, together with notes on the diffusion and loss in remelting of the former element.

T. Gray || gives some diagrams showing the effect of alternate extensions and compressions on cast iron. In general, after slowly applying any given load and taking it off again, the iron can be subjected to nearly as much load repeatedly, and the pen of the recording apparatus

* *Iron Age*, vol. lviii. p. 217. † *Engineering News*, vol. xxxv. p. 324.

‡ *Iron Age*, vol. lvii. p. 1312.

§ Paper read before the Convention of Foundrymen, through the *Iron Trade Review*, vol. xxix. No. 20, pp. 14–19.

|| *The Digest of Physical Tests*, vol. i. pp. 206–211.

follows nearly the same line, making a loop which shows the dissipation of energy during the cycle. The smallest application of tensile stress to a new specimen produces set, which is not increased by repeated applications of the same load. The result is similar but not so marked with compression. The set produced by tensile stress is considerably more rapid after the material has been subjected to compression. For small loads the modulus of elasticity is nearly the same for compression as for tension. It is diminished by repeated alternations of opposite stress.

The Strength of Steel Castings.—C. H. Benjamin * has investigated the strength of small steel castings, which are often used in machinery and purchased in open market. He concludes that their ultimate tensile strength varies from 33,000 to 44,000 lbs. per square inch, with an average of 37,500 lbs. The elastic limit may be taken at half this in tension, and 30,000 lbs. in compression. The effect on the strength of removing scale is very variable, depending on the treatment and method of casting. Some castings are poured at high temperatures, and others when the metal is not sufficiently fluid. For the sake of comparison some tests of malleable castings are given, and these show an average tensile strength of 38,270 to 36,160 lbs., elongation 0·97 to 1·2 per cent., and a shearing strength of 42,560 to 43,100 lbs. as compared with 56,700 to 42,900 lbs. for steel castings. The elongation in the steel castings tested was 0·5 to 2·15 per cent.

Tests of Forgings.—H. K. Landis † gives the analysis of five forgings, and the tensile tests of each before and after treatment by quenching and annealing. One of these is as follows for a forging weighing 40,000 lbs., and containing:—

Carbon.	Manganese.	Phosphorus.	Silicon.
0·47	0·57	0·025	1·34

	Quenching temperature, °F.	Annealing temperature, °F.	Tensile strength, lbs. per square inch.	Elastic limit, lbs. per square inch.	Elongation.	Reduction of Area.
					Per Cent.	Per Cent.
I.	...	...	101,000	...	15·00	36·00
II.	1800	1160	96,000	49,000	17·66	28·40
III.	...	1170	86,800	44,000	25·00	44·50
IV.	1500	1150	89,600	49,000	20·00	43·73
V.	1525	1160	90,000	46,000	20·16	41·08

I. Before treatment; II. After annealing, quenching, quenching, annealing; III. After again annealing; IV. After again quenching, quenching, annealing; V. After again quenching, quenching, annealing.

* *The Digest of Physical Tests*, vol. i. pp. 145–149. † *Iron Age*, vol. lvii. pp. 1020–1021.

The examples are selected from over 4000 treated, and there is nothing to indicate a fixed relation between treatment and tests, though a marked improvement in elongation and reduction of area is apparent.

Tests of Tubes.—In connection with various statements that have recently appeared concerning the reversion to the use of iron for the manufacture of tubes, a number of illustrations have been published * of steel tubes tested under most severe conditions, in order to show that steel can advantageously be used in this industry. At the works where these tubes were made, iron from two blast furnaces is converted into steel in two 8-ton vessels making 3700 tons of finished billets and slabs weekly. The steel is very soft, with 0·06 to 0·07 of carbon and 0·35 of manganese. The crop ends of boiler tubes are broken down flat to test the welds. A certain number are expanded into a tube plate as in use; other pieces broken down endwise under a steam hammer; and samples are also expanded by a drift up to $1\frac{1}{8}$ time their diameter. Hydraulic tests are also used.

Bicycle Tubing,—H. H. Eames † discusses generally the selection of material for bicycle tubing, and states that the factor of safety for bicyles as now made does not exceed $1\frac{1}{4}$. The tubing is subjected to intense vibratory strains, so that it is evident that impurities, such as phosphorus and sulphur, should be absent as far as possible. Probably nickel steel tubes containing 5 per cent. of nickel would be a very suitable material, but it is only made to a limited extent, so that it is only necessary to consider ordinary carbon steel. To obtain the greatest elastic limit in the annealed state, it is only necessary to increase the carbon up to the limit at which the steel can be cold drawn, but the presence of vibratory stresses prevents this simple solution. The experiments with rotating shafts by J. E. Howard refute many preconceived ideas, and show that the greatest resistance to alternate stress is obtained with steel containing 0·50 per cent. of carbon. Analyses of many specimens in actual use, however, only show a maximum of 0·28 per cent., whilst mostly the percentage is only 0·15. The higher-carbon steel with 0·50 carbon can be flanged if phosphorus is low, and can be brazed without injury if care is taken.

The preference expressed for 0·50 carbon steel is supported by J. E. Howard, ‡ who instances other examples where such steel is found to be more advantageous than either harder or milder steels.

* *Iron Age*, vol. lviii. pp. 529–530. † *Ibid.*, vol. lvii. pp. 1425–1426.
‡ *Ibid.*, vol. lviii. pp. 69–70.

Tests of Music Wire.—Some tests made at Watertown Arsenal have shown that there has been a great advance in the tensile strength of music wire of recent manufacture. The maximum strength was found in one of the smallest-sized wires with an actual diameter of 0·0284 inch, and it amounted to 462,870 lbs., or 211 tons, per square inch. The behaviour of tests made with wire having ordinary eyed ends was erratic, owing to the twist put on the wire in twisting the eyes. Some tests made on wires eyed without this torsional set gave better and more uniform results. A sharply-defined elastic limit is not found in this material. Full details of all the tensile and other tests are given.*

Structural Steel.—An exhaustive treatise on the manufacture and properties of structural steel has been published by H. H. Campbell.† The subjects dealt with are the following:—(1) the errancy of scientific records; (2) pig iron; (3) wrought iron; (4) steel; (5) high-carbon steel; (6) the acid-Bessemer process; (7) the basic-Bessemer process; (8) the open-hearth furnace; (9) fuel; (10) the acid open-hearth process; (11) the basic open-hearth process; (12) considerations of certain costs of manufacture; (13) segregation and homogeneity; (14) influence of hot working on steel; (15) annealing; (16) the history and shape of the test-piece; (17) the influence of certain elements on the physical properties of steel; (*a*) effect of certain elements as determined by general experience and by the usual methods of investigation; (*b*) effect of certain elements as determined by special mathematical investigations; (*c*) effect of carbon, manganese, and phosphorus upon the tensile strength of iron, as determined by special mathematical investigations; (18) classification of structural steel; (19) welding; (20) steel castings; and (21) inspection.

The author takes strong ground in regard to the retention of existing trade nomenclature. Thus he closes a discussion in which he severely criticises those writers who have endeavoured to thrust into the English language the terms "weld iron," "ingot steel," &c., by the following:—

"By the term 'wrought iron' is meant the product of the puddle-furnace or the sinking fire. By the term 'steel' is meant the product of the cementation process, or the malleable compounds of iron made in the crucible, the converter, or the open-hearth furnace. This nomenclature is not founded on the resolutions of committees of societies. It is the

* *Report of the Tests of Metals*, Washington, 1895, pp. 317–354.

† "The Manufacture and Properties of Structural Steel." New York: The Scientific Publishing Co., 1896. A copy of this work has been presented by the author to the Institute Library.

natural outgrowth of business and of fact, and has been made mandator by the highest of all statutes—the law of common sense. It is the universal system among engineers, not only in America, but in England and in France. In other lands the authority of famous names, backed by conservatism and governmental prerogative, has fixed for the present, in metallurgical literature, a list of terms which I have tried to show is not only deficient, but fundamentally false."

In regard to the recent controversy concerning the elastic limit and the yield point, the author takes equally strong ground, in the following words:—"These conclusions represent common sense in their summary dealing with the petty theories of enthusiasts, who are so wrapped up in the accurate determination of a micrometrical measurement that they ignore the more important variations inherent in the method itself, not to mention the still more overwhelming differences caused by changes in the history and shape of the material."

The first chapter of the book is devoted especially to a discussion of the differences in results of chemical analysis by different chemists. Then follow chapters on pig iron, wrought iron, and the several metallurgical processes by which steel is made. This portion of the book, which occupies about a quarter of the whole, will be of interest chiefly to metallurgical students. The remainder of the work appeals more directly to the structural engineer. It contains chapters on homogeneity and segregation, influence of hot working, annealing, the history and shape of the test-piece, the influence of certain elements on the physical properties of steel, classification of structural steel, welding, steel casting, and inspection. A great deal of space is given to a mathematical investigation, by the method of least squares, of the problem, What is the influence of carbon, phosphorus, manganese, copper, sulphur, and silicon upon ultimate tensile strength? To solve this problem, the records of 1180 test-pieces were taken, combined into 137 groups, and the average chemical analysis of each group was obtained. An enormous amount of mathematical work was performed upon this mass of data, resulting in the conclusion that the method of least squares is inapplicable to the problem if all the data are included. Thus the mathematical solution gave the absurd conclusion that 0·06 per cent. of sulphur would increase the strength of steel 22,000 lbs. per square inch, when, in fact, it would cause only a very slight increase, if any. By eliminating the factors silicon, copper, and sulphur from the mathematical equation, and applying the method of least squares to the remaining factors, equations were reached which gave results which are probably as close to actual test

records as any formula for relation of strength to chemical analysis can possibly give, though individual tests will frequently show wide differences from the result given by the formula.

The standard specifications adopted by the Association of American Steel Manufacturers in August 1895 have been revised, and are now published * in full. Except in a few details they do not differ from those previously put forward, of which the nature is sufficiently indicated in an abstract in a previous volume.† Chemical requirements are added for structural and plate steel.

On investigating the strength of structural materials, Euler found that a force acting in the sine direction only causes the material acted on to bend when the force has attained a certain degree. He showed that the force was inversely proportional to the square of the length of the bar, and is dependent on the elasticity of the material, not on its tensile strength. The Euler formula, $P = \frac{\pi^2 EJ}{sl^2}$, in which E represents the elasticity, J the least bearing moment of the bar section, l the length of the bar, and s the degree of safety, has been very generally accepted, and has been further investigated by L. von Tetmajer,‡ who has made a number of experiments. He found from 296 tests that cast-iron bars with the ratio $\frac{l}{k} > 80$ may be calculated for according to Euler's formula: $\frac{P}{F} = 9870 \left(\frac{k}{l}\right)^2$, in which $E = 1000$ tons. As soon as $\frac{l}{k} < 80$ the formula (for metric tons and square centimetres) becomes $\frac{P}{F} = 0{\cdot}00053 \left(\frac{l}{k}\right)^2 - 0{\cdot}120\ \frac{l}{k} + 7{\cdot}76$.

Of weld-iron bars 125 were tested, and of ingot-iron bars 69. For the length ratios—

$$\frac{l}{k} \leqq \text{about } 112 \text{ for weld iron,}$$

$$\frac{l}{k} \leqq \text{about } 105 \text{ for ingot iron,}$$

the results were entirely in accord with the Euler formula, so that the formulæ may be calculated for weld iron: $\frac{P}{F} = 19{,}740 \left(\frac{k}{l}\right)^2$, in which

* *Iron Age*, vol. lviii. pp. 407–408.

† *Journal of the Iron and Steel Institute*, 1895, No. II. p. 574.

‡ *Mittheilungen der Materialprüfungsanstalt*, No. VIII. Zurich; *Stahl und Eisen*, vol. xvi. 672–674.

$E = 2000$ tons. For ingot iron this becomes $\frac{P}{F} = 21{,}220 \left(\frac{k}{l}\right)^2$, in which $E = 2150$ tons. For the ratios of length $\frac{l}{k}$ = about 10 to 112 for weld iron, and about 10 to 105 for ingot iron. These formulæ are for weld iron: $\frac{P}{F} = 3{\cdot}03 - 0{\cdot}0129 \frac{l}{k}$, and $\frac{P}{F} = 3{\cdot}10 - 0{\cdot}0114 \frac{l}{k}$ for ingot iron. For the harder varieties of ingot metal, with tensile strengths exceeding 25 tons per square inch, E may be taken as $= 2240$ tons, and the formulæ for $\frac{l}{k} \geqq$ about 105, $\frac{P}{F} = 22{,}200 \left(\frac{k}{l}\right)^2$, and for $\frac{l}{k}$ about 10 to 15, $\frac{P}{F} = 3{\cdot}21 - 0{\cdot}0116 \frac{l}{k}$.

A. C. Cunningham * gives an account of the working of bridge-pins, and shows the necessity for special testing. He gives four tables of tests, and submits specifications as being likely to procure as good bridge-pins as can be had in common practice.

Wepfer † states that wrought iron should be used for the manufacture of round and hexagonal drawn rods utilised for making screws, bolts, and nuts, as it can be worked more satisfactorily than steel.

Steel Rails.—A series of tests has been published ‡ of defective basic rails. These tests are discussed with some notes on European specifications both as to basic and acid Bessemer rails.

A. Martens gives § the results of an investigation of the influence of the degree of heating during rolling on the tensile properties and the microscopic structure of steel rails. The experiments were made with rails that were cooled before the two last passes through the rolls. They showed that the tensile strength and the ductility increase with the rolling heat.

A number of tests have been made ‖ of the deflection in rails produced by passing locomotives. Fibre stresses amounting to 13,810 lbs. per square inch were found with the track in normal conditions, and 16,430 lbs. when one sleeper was removed. Sections of the rails used are given, and the measurements made are represented in graphic form.

* *Proceedings of the American Society of Civil Engineers*, vol. xxii. pp. 306-314.

† *Baumaterialienkunde*, vol. i. p. 27.

‡ *Engineering News*, vol. xxxvi., August 27, 1896.

§ *Mittheilungen aus der königlichen technischen Versuchsanstalt*, vol. xiv. p. 89, with three figures.

‖ *Tests of Metals*, Washington, 1895, pp. 367–371, with fourteen plates.

Railway Axles.—T. Andrews* gives the results of a lengthy investigation upon the effect of strain upon railway axles, and their minimum flexion resistance point. No less than 285 wrought iron and steel axles weighing about 57 tons were tested to destruction during the experiments, which were arranged in twelve sets. These related to the increase of rigidity under the influence of increasing series of slow flexion stresses at ordinary temperatures, at zero Fahrenheit, and at various temperatures up to 1472° F.; to tensile tests of the metal of the axles; to the influence of torsional stresses and tensile stresses; and also to impact tests. The whole of the experiments coincide in indicating an increase of rigidity in railway axles under the influence of the varied kinds of stress and strain applied (beyond the elastic limit), the extent of the increase of rigidity varying according to the nature of the metal, the conditions of temperature, and the kind of stress; the effects of stress being similar, whether produced by slow flexion, impact shocks, torsional, tensile, or other stresses. The results also show that the greater the stress to which the metal was submitted, the greater was the increase of rigidity, and decrease of elongation, and consequent deterioration of its physical properties. Steel axles, both Bessemer and open-hearth, are shown to increase in rigidity under concussional shocks more than wrought iron ones. A marked decrease in resistance to flexion stress is manifested at 212° F., and a similar reduction of flexion endurance at 572° F. This shows the danger of overheated necks while running. The numerical results of the tests are given in a number of tables, and illustrations are given of the fractures.

The committee appointed by the Master Car Builders' Association have drawn up specifications for steel and iron axles.† The chemical composition prescribed for steel axles is :—

Carbon.	Manganese. not above	Silicon.	Phosphorus. not above	Sulphur. not above
0·40	0·50	0·05	0·05	0·04

Axles are to be tested by drop tests under a tup of 1640 lbs. on supports 3 feet apart, on an anvil of 17,500 lbs. resting on springs. They will be rejected if they break in any way as a result of five blows of the tup falling 43 feet, or if the first blow produces a deflection exceeding 6½ inches. The finish of the delivered axles is also dealt with.

* *Transactions of the Society of Engineers*, 1895, pp. 181–234, with three plates.

† *Report of the Master Car Builders' Association*, vol. xxx. pp. 172–178, with plates.

Tests of Nickel Iron Alloys.—M. Rudeloff * has published the fourth report of the committee investigating, under the presidency of H. Wedding, the alloys of nickel and iron. The analyses of the ingots examined showed the following percentage compositions:—

Ingot.	Nickel, Intended.	Nickel, Actual.	Fe.	Co.	Cu.	Mn.	Si.	Al.	S.
1–3	0·0	0·05	99·59	0·01	0·06	0·05	0·04	0·06	0·02
4–5	0·5	0·76	98·98	0·04	0·07	0·06	0·03	0·02	0·02
7–9	1·0	1·01	98·75	0·02	0·04	0·05	0·04	0·05	0·02
10–12	2·0	2·05	97·72	0·05	0·06	0·03	0·06	0·03	0·02
13–15	3·0	3·00	96·63	0·06	0·07	0·03	0·06	0·03	0·02
16–18	4·0	3·98	95·81	0·07	0·06	0·02	0·05	0·04	0·02
19–21	5·0	4·92	94·81	0·09	0·07	trace	0·05	0·05	0·02
22–24	8·0	7·84	91·89	0·11	0·06	trace	0·04	0·07	0·02
25–27	16·0	15·59	84·12	0·13	0·06	0·00	0·05	0·07	0·02
28–30	30·0	29·77	69·74	0·28	0·05	0·02	0·05	0·03	0·02
31–33	60·0	59·60	39·69	0·49	0·10	0·00	0·06	0·00	0·01
34–36	95·0	93·68	5·15	0·98	0·08	trace	0·08	0·00	trace
37–39	100·0	98·39	0·33	1·03	0·07	0·00	0·10	0·00	trace

There were also slight percentages of magnesium, varying, with the exception of ingots 31 to 39, from a trace to 0·03. In ingots 31–33, 0·07 per cent. was present; in ingots 34–36, 0·09 per cent.; and in ingots 37–39, 0·12 per cent.

The full results of the mechanical tests of these alloys are given, and these show that with increasing percentages of nickel, the tensile strength rises until with 8 per cent. of nickel it reaches 35·7 tons per square inch, the limit of elasticity being at 28·06 tons. As the tensile strength increases so the elongation diminishes. The next alloy in the series, that with 16 per cent. of nickel, had a tensile strength of 26 tons, with only 0·9 per cent. elongation. The next alloy, that with 30 per cent. of nickel, had a still lower tensile strength—6·9 tons—but it would appear that from this percentage upwards the strength and the elongation increase; for the next alloy, with 60 per cent. of nickel, had 38 per cent. of elongation, and a tensile strength of 34 tons. Beyond this the elongation and tensile strength again diminished. The alloy with 15·60 (16) per cent. of nickel showed the greatest resistance to a shearing force—considerably more than double that of the lowest alloy of the series, and nearly double that of the highest number, the respective figures being: 16·89 tons for the alloy with 0·05 per cent. of nickel, 42·98 tons in the case of the 15·6 per cent. alloy, and 22·03 tons in that of

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 240–241.

the alloy containing 98·39 per cent. of nickel. Other details as to the behaviour of these alloys under stress are also given.

D. H. Browne * quotes some of the recent tensile and crushing tests made by Professor Rudeloff on alloys made by melting nickel with pure wrought iron to show that the addition raises the final strength, and in a still more marked degree the elastic limit. A selection of recent tests of nickel steel is also given to show that the same results are obtained. The effect on hard steels is also to reduce the liability to crack. Nickel also affects the strength of cast iron, though not to the same degree as in the case of steel. Some 3 per cent. increases the transverse strength about 12 per cent., and it decreases the depth of chill. In general terms, the effect of nickel in increasing the strength of wrought iron, steel, and cast iron seems to be in inverse proportion to the amount of carbon present. The added strength is proportionately greater in tool steel than in cast iron, greater in soft steel than in hard, and is especially noticeable in pure wrought iron. Its greatest use is therefore in alloy with mild steel and wrought iron.

W. Beardmore † gives the results of investigations with a view to proving that what can be done with carbon steel can more advantageously be accomplished with nickel steel.

Tests of Vanadium Alloys.—It was pointed out by Sefström as far back as 1830 that the pig iron made in Sweden from the Tåberg magnetites contained vanadium, and that this element was present in the wrought iron produced from this pig iron. It was not entirely eliminated, that is, by the oxidising treatment to which the pig iron had been subjected. Several kilogrammes of the iron only yielded a gramme and a half of vanadium, but much larger quantities were contained in the forge slag. Osmond has shown that many other slags contain considerable quantities of this element, especially slags from the Bessemer process. According to Vosmaer, the Creusot works produce annually about 60 tons of vanadic acid from their blast-furnace slags. Riley found 0·686 per cent. of vanadium in a Wiltshire iron, and J. E. Stead found from 0·168 to 0·262 per cent. in four samples of pig iron examined, the highest percentage being in Cleveland iron.

The Tåberg iron was the softest Swedish iron then produced (1832),

* *Engineering and Mining Journal*, vol. lxi. pp. 468–469.

† *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, vol. xxxix. pp. 229–248.

and K. Hélouis * considered from this, and from the fact that Staffordshire slags often contain much vanadium, while the metal made is very extensible, that if vanadium were added to steel it ought to toughen it. Other experiments are necessary, but those made by the author appear to show that vanadium increases the tensile strength and reduces the elongation. Steel containing 1 per cent. of vanadium was found to be capable of attaining great hardness on hardening.

In order to test the effect upon steel, a mild steel free from phosphorus, with a tensile strength of 30 tons per square inch and 17 per cent. elongation, was melted in a graphite crucible alone, when it became somewhat strongly carburised, showing 61 tons tenacity and 23 per cent. elongation, which was raised by the addition of 1 per cent. of vanadium to 69 tons and 7·3 per cent., with the elastic limit of 50 tons. The same mild steel, when melted in a magnesia-lined crucible to avoid absorption of carbon, gave, with the following proportions of vanadium—

	Tensile Strength.	Elongation.
	Tons per Sq. In.	Per Cent.
0·5 per cent. (unannealed)	42·0	16
1·0 ,, ,, ...	61·5	14
1·0 ,, (annealed)	45·0	20

The latter metal, although very soft when annealed, becomes extraordinarily hard by tempering. Ordinary malleable iron of about 24·5 tons tenacity and 19 per cent. elongation was changed by the addition of 0·5 per cent. of vanadium to 39 tons and 12 per cent. in the forged bar, and 33·7 and 32 per cent. elongation when annealed. The latter result has attracted considerable attention for the remarkable malleability and ductility indicated.

Compressed Gas Cylinders.—C. Bach † publishes a number of illustrations showing the results on three cylinders of their explosion when filled with compressed carbon dioxide. In two of these cases workmen had been killed by the explosion. The result of the investigation has in each case shown that if the explosion of such cylinders is to be avoided, the metal used in their construction must not only possess an adequate degree of strength, but of toughness also. They must be

* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 5th Series, vol. i. pp. 904–908.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xl. pp. 672–673, eight illustrations.

sufficiently thick, too, and must be very carefully annealed after manufacture. Tests of the metal made of test-pieces cut from the cylinders after explosion showed in each case that the annealing after manufacture had either not been performed at all, or at least only to a very inadequate extent.

A. Martens * deals similarly with the cylinders used for compressed hydrogen. Four hundred bottles filled with the gas, and intended for use in ballooning, exploded. The author publishes elaborate details of the tests to which he subsequently subjected the metal in these exploded cylinders. He agrees with the previous author as to the kind of material to be employed and the necessity for adequate annealing, and deals generally with the tests to be made and precautions to be taken in the manufacture, and in insuring that acid vapour does not pass into the cylinders with the compressed gas with which they are to be filled.

Armour-Plate Tests.—In the *Naval Annual* for 1896, Captain Orde Browne † gives his usual summary of the recent trials of armour-plates and projectiles made throughout the world. In spite of the opinion of many artillerists, armour has not been driven out of the field by the power of the gun, but it has constantly been improved by the introduction and application of new processes. Thus the Harvey process, or some alternative for it, to give the armour a hard face, has come in nearly everywhere. The author shows from the trials quoted that great results have been obtained by double-forged plates in America, and that any difficulties attending the use of nickel have been so far mastered that plates containing it have shown a combination of toughness and hardness not hitherto attained by other means, especially in the case of thick armour. This is seen in a most remarkable way in a plate 11·8 inches in thickness made by Krupp, which successfully resisted two shots capable of penetrating 2·19 times its thickness of wrought iron. The highest estimate made until recently was $1\frac{3}{4}$ times the thickness. This standard has probably only been approached hitherto by thin plates. Nickel plates and double-forged plates have now been made experimentally at Sheffield, and the author hopes that this reversion to nickel will again place this country in the forefront. In projectiles great strides have also been made. The author then gives an account of the various trials, of which particulars have been given in previous volumes of the *Journal*.

* *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xl. pp. 717–723 and 749-75 , fourteen illustrations and tables.

† *The Naval Annual*, 1896, pp. 343–364, with illustrations.

In an article * in the *Engineer*, entitled "Herr Krupp on the Perforation of Steel Armour," it is shown that the investigation of the laws of perforating armour at high velocities has not been satisfactorily attempted. In each country the local projectiles are tried against locally produced plates, and the use of Holtzer's projectiles as a sort of universal standard appears to have been dropped. The various formulæ for the perforation of armour are then considered and reduced to a common form. On steel plates with hardened faces, a striking velocity of 2000 foot-seconds will give about the calibre perforation. This article is discussed by C. A. Stone,† who shows that the formulæ presuppose that the projectile would perforate the plate unbroken, and but little deformed. With hard-faced armour, which breaks up the projectile, these formulæ are not applicable.

A test of an experimental turret was made at Indian Head on May 9. The structure weighed 67 tons, and carried 157 tons of armour, with 180 tons of iron inside to represent the guns, &c. Three shots were fired, weighing 300, 350, and 850 lbs., and were fired with striking velocities of 1680, 1700, and 2000 foot-seconds respectively. The turret structure as a whole shows no sign of deformation. A number of projectile tests were also made at this ground on May 22, June 3, and June 16.‡

Captain W. H. Jaques § states that the United States and Germany have produced armour fully 15 per cent., if not 20 per cent., better than the best plain steel Harveyised armour that Great Britain has placed upon her battleships. The use of nickel is advocated by the author on the ground that increased excellence conduces to actual economy. He considers that his country has an excellent record in manufacturing progress in ordnance for the year.

* *Engineer*, vol. lxxxii. p. 1.

† *Proceedings of the United States Naval Institute*, vol. xxii. pp. 659–660.

‡ *Ibid.*, pp. 494–497.

§ Paper read before Section G of the British Association; *Iron Age*, vol. lviii. p. 766; *The Engineer*, vol. lxxxii. p. 323; *Engineering*, vol. lxii. p. 452.

CHEMICAL PROPERTIES.

The Diamond in Steel.—L. Franck * observes that three or four years ago the diamond form of carbon was found in the Cañon Diablo meteorite. The observation was made about the same time as to the occurrence of the diamond in olivine. Our knowledge became widened as to the terrestrial occurrence of the diamond, and this discovery, taken in conjunction with the discovery in meteoric iron, pointed to the diamond having had its origin in a pyro-chemical process. It was further deducible that the diamond had its origin in a crystallisation under conditions of temperature and pressure such as exist in the molten interior of the heavenly bodies during their gradual cooling down. It was probable, therefore, that it would form from molten iron at high temperature and pressure. Moissan observed experimentally that this was the case. Rossel suggested that it was possible that ordinary steel might contain diamonds, and the author now describes a number of experiments which show that this is the case. The author took samples of steel and submitted them to the action of a number of solvents, and then examined microscopically the residues left. It was possible to distinguish in these (1) a dark grey iron carbide, very closely resembling in appearance the carbide FeC_4 obtained by repeated fusion of iron with an excess of carbon; (2) an octahedral iron carbide which is probably Fe_3C_2; and (3) undeterminable carbides. It was also possible to distinguish several forms of carbon :—(*a*) a light carbon, probably resulting from the decomposition of the iron carbide; (*b*) a carbon in the form of very thin striped, chestnut-brown coloured pieces with a jagged appearance; (*c*) fine black graphite crystals, among which were some that reflected so much light that at first sight they appeared transparent. A further examination of these has been commenced.

A number of other transparent crystal fragments were also discernible. The whole residue was then successively treated with hydro-

* *Stahl und Eisen*, vol. xvi. pp. 585–588, with sheet of illustrations.

fluoric acid, concentrated sulphuric acid, and sulphuric acid diluted to 1·8 specific gravity, then dried, fused with potassium chlorate, washed with water, treated with boiling fuming nitric acid, and again with hydrofluoric and sulphuric acids. The residue after washing was finally placed in bromoform. After each successive treatment the residue was examined microscopically. Finally there remained in the residue some small though well-formed octahedra, which proved to be diamonds.

In another experiment, a sample of rolled steel from the Düdelingen works in Luxemburg was examined with similar results. The author states that the results so far obtained show that unhammered and unrolled steel yields well-formed octahedral diamonds, and that steel which has been hammered or rolled contains fragments of these; and, further, that the higher was the temperature at which the steel was made, the greater was the quantity of diamond found.

According to A. Rossel,* small diamonds have been obtained from hard steels produced at high temperatures and cooled under great pressure. The steels were treated according to the methods recommended by Berthelot and by Moissan. The crystals have the same form, appearance, and properties as those described by Moissan.

Carbon in Iron.—Baron H. von Jüptner † points out that the so-called "combined" carbon is now believed to exist in the various kinds of iron in two modifications—(1) carbide, and (2) hardening carbon—but it remains uncertain whether they are in the form of true compounds or in that of alloys. The author deals with the work which has thus far been done in connection with this subject. On treating steel drillings with iodine, Eggertz in 1875 obtained a residue having the formula $C_{80}I + 20H_2O$. By treating the metal with salts of copper, Blair with copper-ammonium-chloride obtained residues of the formula $(C_{50}H_{21}ClO_{15})_3NO_2$. Schützenberger and Bourgeois, on treating white pig iron with copper chloride and iron chloride solution, obtained the residue $C_{11}H_6O_8$, which on treatment with nitric acid is converted into $C_{22}H_{17}(NO_2)O_{11}$. Zabudsky, by treating white pig iron with sodium-copper chloride, obtained the residue $C_{12}H_6O_8$, and from this the compound $C_{60}H_{29}IO_{15}$. E. Donath obtained $C_{58}H_{33}O_{29}$ (or, perhaps, $C_{60}H_{34}O_{30}$), and from this $C_{47}H_{32}(NO_2)_2O_{25}$ and $C_{21}H_3(NO_2)O_{17}Ba_3$.

* *Comptes Rendus de l'Académie des Sciences*, vol. cxxiii. pp. 113–115.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 211–217.

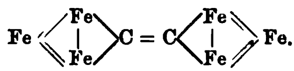
By dissolving the metal by Weyl's method, Zabudsky obtained $C_{12}H_6O_8$; Osmond and Werth for hammered steel cooled without any precautions $15Fe_3C + C_{17}(H_2O)_{15}, C_6$ escaping in the gaseous form; the annealed metal yielded $20Fe_3C + C_{18}(H_2O)_{15}, C_2$ escaping as gas. Hardened in water the metal yielded $Fe_3C + C_4(H_2O)_3, C_3$ escaping as gas; hardened and annealed the metal gave $3Fe_3C + C_4(H_2O)_3$, C_2 passing off as gas. Arnold and Read obtained Fe_3C in two different modifications.

By decomposing with silver chloride Zabudsky obtained $C_{12}H_6O_3$, and with chromic and sulphuric acids Abel obtained from cold rolled cement steel $10Fe_3C + Fe_2C(H_2O)$; from annealed cement steel $15Fe_3C + C(H_2O)$; from tempered cement steel $21Fe_3C + C_3(H_2O)_5$; and from cold rolled steel of a different kind $28Fe_3C + {}_2C_3(H_2O)_2$. Using dilute sulphuric acid, Müller obtained Fe_3C and FeC_3. Prost and De Koninck have shown that, using hydrochloric acid, the hydrogen contained in the undissolved residue increases with increasing concentration of the acid from zero to a maximum, the iron gradually diminishing at the same time from a maximum to zero. The percentage of carbon, too, is reduced, but not to zero. They therefore conclude that there are many carbides present in the residue. Solution in ether gave $C_{11}H_{18}O$. Behrens and Von Linge's investigations, the author observes, are of especial importance. These led them to pronounce in favour of the formula Fe_3C for the carbide of white pig iron, rather than for the formula Fe_4C. In Dannemora iron the percentage of hard carbide is about 10, and all the phosphorus appears to pass into this. Whether the carbide of cement steel is crystalline or not they could not say definitely. In the case of manganiferous phosphoric white pig iron it is certain that on solidification a softer grey and a harder white substance separate, both of which are crystalline.

Using nitric acid, Osmond and Werth obtained $FeC_{27}(H_2O)_9O_9(NO_2)$, or $9[C_3(H_2O)O]NO_2Fe$.

The gases escaping on the solution of iron and steel have been examined by Helge Bäckström and Gumnar Paijkull, who found that—(1) the carbon escaping as hydrocarbon is not proportional to the combined carbon; (2) in no one of the kinds of iron examined was either the whole of their contents of combined carbon, or a proportionate quantity of it, given off as gas; (3) hydrochloric acid yields large quantities of gas, and more carbon in it than does sulphuric acid of similar strength; (4) the volume of gas produced is not proportional to the chemically combined carbon; and (5) hardened steel gives a larger quantity of gas, and a gas richer in carbon than does unhardened steel.

The author observes that it is very difficult indeed to bring all these different investigations into line, and to obtain any clear idea of the different ways in which the carbon occurs in iron and steel. Only future investigation, systematic and detailed in character, can give us this information, and at present everything is mainly in the condition of hypothesis. Graphite and temper carbon probably occur in different modifications, but not dealing with these, the author proceeds to discuss the question of the so-called "combined" carbon. He is of opinion that that carbon which passes off into gas under treatment with hydrochloric or sulphuric acid must exist in at least two forms, in one which passes off at the first stage of the solution, probably as CH_4, and in a second which escapes at a later stage, probably in the form of C_2H_2. That Fe_3C exists in tempered steel seems certain, but whether the formula is this or a multiple of it, is uncertain. He thinks that a part of the hardening carbon may be present as a carbide of some such formula as



The result obtained by Prost of $C_{11}H_{18}O$ from an extraction by ether of the undissolved residue, points to the existence of yet another carbide. The carbide Fe_3C contains a large proportion of the phosphorus present in the iron, apparently as Fe_3P and Mn_3P_2. It is possible that in the separation of the phosphides the phosphorus may liberate carbon from the carbide Fe_3C, perhaps as temper carbon, or possibly as FeC_3. At least three or four kinds of "combined" carbon appear to exist; and microscopic investigation should afford some evidence of these. The author, therefore, deals with Osmond's recent investigations on the subject.*

Baron H. von Jüptner † observes that the maximum quantity of carbon that can be taken up by iron, depends on the other elements that are also present. For pure iron, Percy placed this maximum percentage at 4·63, a percentage that does not correspond with any simple chemical compound. This maximum percentage is increased by the presence of chromium and manganese, but is diminished by that of most of the metalloids. The author quotes from Ledebur's *Metallurgy of Iron*, showing that the possible degree of saturation of manganese for carbon in manganese iron alloys is almost entirely

* *Journal of the Iron and Steel Institute*, 1896, No. I. pp. 209–211.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 447–449.

independent of the iron present. It amounts to about 0·0775 part of carbon for each part of manganese, and consequently corresponds approximately to the formula Mn_8C_3. The ratio of the power of solubility of iron for carbon is to that of manganese for this element as 3 : 5. Similarly, in chrome iron alloys the percentage of carbon that the chromium will take up appears to remain uninfluenced by the iron present, one part of chromium corresponding approximately to 0·116 of carbon, which is in agreement with the formula Cr_2C, or in other words, chromium will absorb more than ten times as much carbon as iron, and more than six times as much as manganese, the ratio being 3 : 5 : 31. The presence of silicon and sulphur diminishes the solubility for carbon, but never destroys it entirely. This is much the same in the case of phosphorus; and it is a most interesting observation that one atom of phosphorus appears to replace one atom of carbon, while one part by weight of silicon corresponds to three-sevenths part of carbon, and one part of sulphur to three-eighths of carbon. The author thinks that Donath's suggestion as to the constitution of carbon iron compounds might be made to include silicon, sulphur, and phosphorus compounds also.

New Carbides.—H. Moissan * has produced in the electric furnace the carbide Mn_3C. This has the specific gravity of 6·89, and decomposes water at ordinary temperature according to the reaction

$$Mn_3C + 6\ H_2O = 3\ Mn\ (HO)_2 + CH_4 + H_2.$$

Other carbides similarly produced are those of yttrium and thorium, C_2Y and C_2Th, the former having the specific gravity 4·13 and the latter 8·96. Zirconium yields the carbides CZr and C_2Zr. These do not decompose water. Chromium yields the carbides C_2Cr_3 and CCr_4; molybdenum, the carbide CMo_2; titanium, CTi. Neither of these latter show any action with water at the ordinary temperature. The carbides of the earths, having the formula C_2R, yield pure acetylene with water; LiC_2, which Moissan has recently prepared, does this as well as the carbides of calcium, barium, and strontium. Aluminium carbide, C_3Al_4, as Lebeau has shown, and those of glucinum or beryllium (CGl_2), give methane. Uranium carbide has the formula C_3Ur_2. It possesses strong metallic lustre, and has the specific gravity 11·28. It is slightly less hard than quartz, and gives sparks when struck with a harder material, and with careless powdering in an agate mortar will

* *Stahl und Eisen*, vol. xvi. p. 366.

take fire. This carbide shows a different behaviour with water to those above referred to. It yields not one hydrocarbon, but several of different kinds. The carbides of cerium, C_2Ce, and of manganese show similar behaviour. The metallic carbide, C_2Ce, of inorganic origin, yields, when treated with cold water, gaseous, liquid, and solid hydrocarbons, a fact, as Moissan observes, which is of much importance. It is of interest to note that though in Mendelejeff's periodic law zirconium comes close to thorium, the properties of the carbides of these two elements differ greatly from each other.

Preparation of Alloys.—According to H. Moissan,* many alloys can be obtained by taking advantage of the ease with which metallic oxides are reduced by aluminium. The general method is to throw a mixture of aluminium filings and the oxide of the particular metal into melted aluminium. Part of the aluminium burns, and there is such an energetic development of heat that the most refractory oxides are reduced, the metal mixing with the excess of aluminium. In this way alloys of aluminium with nickel, molybdenum, tungsten, uranium, and titanium have been prepared. An alloy can be obtained containing as much as 75 per cent. of tungsten. The direct preparation of a copper-chromium alloy is difficult, but an aluminium-chromium alloy is readily obtained in the manner indicated, and this dissolves in all proportions in fused copper, forming a copper-aluminium-chromium alloy, from which the aluminium is readily eliminated by stirring in cupric oxide, a copper-chromium alloy being left. A similar method can be applied to the introduction of tungsten and titanium into open-hearth steel.

Preparation of Chemically Pure Iron.—W. A. M'Gillivray † gives the result of investigations carried out at the suggestion of the late Professor William Dittmar. The methods arrived at are by reduction of anhydrous ferrous chloride, and by reduction of ferric oxide.

Silicides of Iron.—By heating a mixture of iron filings, sand, and charcoal in an electric furnace, G. de Chalmot ‡ obtained a silicide containing 23 to 27 per cent. of silicon. Occasionally it forms crystals about 1 centimetre long of a pure ferric silicide of the formula

* *Comptes Rendus de l'Académie des Sciences*, vol. cxxii. pp. 1302–1303.

† *Industries and Iron*, vol. xxi. pp. 69–70.

‡ *Journal of the American Chemical Society*, vol. xvii. pp. 923–924.

Fe_3Si_2. It is white and crystalline, of specific gravity 6·36, hard, brittle, and only slightly magnetic; but it is a good conductor of electricity. It is only fairly proof against oxidising acids, but is slowly attacked by cold nitro-hydrochloric acid (1 : 3), which, however, chiefly dissolves the iron, but scarcely any silicon. Fusion with potassium nitrate and potassium sodium carbonate, or treatment with hydrochloric acid, soon breaks up the compound.

The author also obtained a compound approaching the formula $FeSi_2$, which had a specific gravity of 4·851, was non-magnetic, and was scarcely acted on by aqua regia.

Tungsten and its Uses.—J. Castner * draws attention to this element, referring to an article which has appeared † on the uses that can be made of it. The foremost of these are its uses in warfare. The first suggestion of the use of tungsten for shot was made by Mieg some fifteen years ago. He points out that a steel shell filled with a material of so high a specific gravity as tungsten would prove very satisfactory for bullets of small calibre.

Tungsten is very hard, and has a high tensile strength, but is almost wholly wanting in elasticity. With iron, tungsten forms alloys which may contain up to 80 per cent. of tungsten; but the high percentage alloys, which might prove useful owing to their high specific gravity, are very infusible, and extremely difficult to deal with on account of their extreme hardness.

The Corrosion of Wrought Iron and Steel.—H. M. Howe ‡ has investigated the evidence bearing on the relative corrosion of wrought iron and steel, both with regard to industrial and laboratory tests. Of these the former, when sufficiently extended, may be held to be the more valuable of the two, because, for all that is known, they may necessarily imply conditions which work powerfully in favour of one or the other of these two classes of iron, conditions which, if they do not escape analysis, may at least easily escape foresight in planning our laboratory tests. But this industrial evidence must be very extended to be trustworthy, because the conditions of industrial use are liable to vary so very greatly. In view of these variations, great

* *Stahl und Eisen*, vol. xvi. pp. 517-518.

† *Zeitschrift für Berg-, Hütten- und Maschinen-Industrie*, December 10th and 17th, 1895.

‡ *The Mineral Industry*, New York, vol. iv. pp. 429–445.

caution is required in comparing the corrosion of wrought iron at one place or time with that of steel at another place or time, and even when these two classes of iron are simultaneously exposed side by side in industrial use there may often be unnoticed differences in condition which work in favour of one or the other class so as to vitiate the comparison. The mere fact that the wrought iron and steel are in actual contact or even that they are electrically connected might hasten the corrosion of one and retard that of the other to such a degree as to make a great difference in their rate of corrosion, a difference which might disappear wholly were each of the two completely isolated from the other. So, too, slight differences in the position of the two metals, differences in the temperature or in the velocity of the water to which they are exposed, in their contact with copper or other metals, and a dozen other causes, may in industrial use vitiate the comparison. Besides these rather general considerations, there is one which applies especially to this case, viz., that under identical conditions of exposure not only different classes, but even apparently like pieces of wrought iron corrode at very unlike rates, and so do apparently similar pieces of steel.

Wrought iron has been in use in exposed situations for many years without showing material corrosion. Sluices, for instance, exist that are forty-nine years old, and will apparently endure another fifty years, and similarly, wrought iron pipe has been in use over twenty-five years. Welded steel pipe has recently been attacked as particularly liable to corrosion, but this may be due to the necessity for using a soft, easily weldable steel, and this quality is particularly liable to blowholes. W. E. Koch states that extensive observations and experiments show that steel containing blowholes corrodes, but that steel free from blowholes, if it contains a fair quantity of manganese and is not unusually free from phosphorus, resists corrosion as well or better than wrought iron. Corrosion in large steel water-mains is very slight, and experience of over ten years with steel-built vessels on the Great Lakes shows that the loss by rusting is almost negligable.

Between the corrosion of wrought iron and steel there may be a slight constant difference, of constant sign, or there may, under certain conditions of composition, manufacture, or exposure, or both, be a very considerable difference, the sign of which may vary with these conditions; or there may be both such slight constant and such marked occasional difference; or there may possibly even be equality; but a great and constant difference certainly seems irreconcilable with our

industrial evidence. The differences and fluctuations in opinion are readily accounted for by the known great variations in the corrodibility of each class, and by the varying effects of different conditions of exposure. The relative credit of iron and steel is continually fluctuating. It is often argued that under the conditions of some important uses steel probably does on the whole corrode materially faster than wrought iron, at least in certain cases. The distribution of the evidence indicates that if steel is at a disadvantage anywhere, it is in sea-water uses.

Turning now to laboratory experience, two questions are discussed:—

(1) Under given conditions of exposure, how does the corrosion of low-carbon steel compare on an average with that of wrought iron?

(2) Still under given conditions of exposure, how does the fastest corrosion of low-carbon steel compare with the fastest corrosion of wrought iron?

After stating briefly the difference between wrought iron and steel, the most trustworthy laboratory experiments are tabulated.

In only three, or at most four, of these sets of conditions is the evidence sufficiently abundant and harmonious to allow valuable inferences as to the net effect of the generic differences. These are immersion (1) in pure cold fresh water; (2) in pure cold sea water; (3) in boiling sea water; and (4) in acidulated water. Taking a mean of each of these groups, it is found that in fresh water low-carbon steel and wrought iron corrode at the same rate; in cold sea water steel is slightly the more corrodible; in boiling sea water it is much the more corrodible; while in acidulated fresh water its advantage over wrought iron is very great, far greater than its disadvantage in boiling sea water.

Immersed in	Number of Pieces.		Number of Sets of Observations.	Number of Observers.	Ratio A. Corrosion of Steel ÷ Corrosion of Wrought Iron.
	Wrought Iron.	Soft Steel.			
Fresh water . . .	11	13	6	3	0·96
Cold sea water .	22	17	8	6	1·13
Boiling sea water .	21	12	3	1	1·51
Acidulated water .	13	9	7	5	0·36

Under miscellaneous conditions of exposure, in laboratory tests, steel corrodes much faster than wrought iron when exposed to the weather, when alternately wet and dry, and when immersed in alkaline

water; slightly faster than wrought iron in boiling brine and in steam; at the same rate as wrought iron in bilge water and in cold brine. But as to no one of these conditions is there sufficient evidence to yield any strong inference.

As regards the maximum corrosion of wrought iron and steel, a table is given to show that steel compares with wrought iron in regard to the maximum rate of corrosion very much as it does with regard to the average rate. In boiling sea water the results are less favourable to steel, while in acidulated water steel stands very much better than wrought iron.

Looking at these laboratory results in a general way, the behaviour of soft steel and wrought iron is so nearly alike in fresh water, as to indicate very strongly that the generic differences between these two classes have no important resultant effect on corrosion. Such differences as are found, inclining first in one direction, then in the other, are far more probably due to specific variations between the different members of each class. The same is true of their behaviour in cold sea water, if the results of a single observer be neglected. There are, however, strong suggestions of a generic difference unfavourable to steel in boiling sea water, and very strong evidence of such a difference in favour of steel in acidulated water. The general teaching of the laboratory tests compared with that of the industrial tests appears to show a certain harmony. The long and still extending use of steel for important purposes for which corrosion is of the first moment agrees with the inference that there is no important constant difference between wrought iron and steel as to corrosion in cold sea and cold fresh water, no such difference as would exist were the generic differences between them decidedly unfavourable to steel. On the other hand, the belief that steel corrodes more than wrought iron is of such a vague nature and of such distribution that it may well be due jointly (1) to the occasional use of heterogeneous (segregated or imperfectly mixed) steel or of steel of improper composition or containing blowholes—*i.e.*, to the preventable disqualifications, (2) perhaps to the influence of Phillips' paper, and (3) to actual moderate inferiority of steel in boiling sea water.

It is misleading to say either that normal low-carbon steel corrodes more or that it corrodes less than wrought iron, since their relative corrosion varies with the inclosing medium. There is strong reason to believe that such steel when carefully made, free from blowholes, not worked cold nor injured by punching, by shearing, or by other

treatment, nor prejudiced by galvanic contact with other metals, resists corrosion in fresh water as well as wrought iron, in cold sea water at least nearly as well as wrought iron, and in acidulated water better than wrought iron.

The paper read by W. Parker, in May 1881, before the Iron and Steel Institute, on the Rusting of Iron and Steel, led Messrs. Krupp to institute a further series of experiments. These were performed by H. Otto,* who now describes the results. The actual cause of rusting was much discussed after Parker's paper. Some attribute it to the manganese, others to the carbon, and others again to the silicon present. In the experiments now described, metals of different percentages in manganese and carbon were chosen, and it was thought advisable only to compare open-hearth metal and weld iron. Sheets only were examined; these were in part annealed, and in part unannealed. The rusting was effected by hanging the sheets (1) in ordinary air; (2) in warm moist air; (3) in warm feed water; (4) in a boiler in use; (5) alternately in "sea" water, prepared from salt and atmospheric air. Each series of tests consisted of the examination of twenty-two test pieces, each 150 mm. in length, 100 in width, and 10 in thickness. They consisted of (1) ingot iron boiler plates; (2) ingot iron ship plates; (3) soft open-hearth steel plates; (4) spring-hard open-hearth steel plates; and (5) boiler plates of weld iron, the poorest quality of which corresponded to about the quality of the weld iron ship plates as usually employed in Germany. The quality of the boiler and ship plates was that required by Lloyds, and all plates examined were thoroughly analysed and tested generally. The results are shown in curves, and a description is given of the way in which the tests were performed. The quality and chemical composition of such sheets differs now from what they were fifteen years ago, and this must be taken into consideration in connection with these results. The surfaces of the test pieces were all equally good. Series 1 was tested during 1289 days, 722 of which were dry and 567 rainy. Series 2 were hung in the warm air, above a large battery of boilers in a walled space. The various series of experiments were all of long duration. The curves given show that the difference in the degree of rusting between the annealed and the unannealed sheets was very much greater in Series 1, 2, and 5, than in Series 3 and 4. It was greatest in Series 2, that is to say, in those test pieces which were subjected to the action of warm moist air. Next to Series 2 comes Series 5,

* *Stahl und Eisen*, vol. xvi. pp. 561–568, with tables and sheet of illustrations.

then Series 1, and, finally, with a much less degree of rusting away, Series 3 and 4. This rusting was greatest, as stated, in warm moist air, and it was least in the water of a boiler in regular use. Comparing the tests in the various series, and beginning with those of 4—in a boiler—where the action was the least, it is found that the relative degree of rusting of the different metals examined varied but little, being practically nil in the case of the unannealed spring steel, and but 0·50 per cent. in the annealed soft steel. In Series 3—rusting in feed water—the weld iron showed slightly more favourable results than did the ingot iron, and this, too, was the case in Series 4. The weld iron in 3 rusted 1·05 per cent., the ingot iron ship plates 1·2, and the ingot iron boiler plates 1·22 per cent., but here again the difference after all is so small that the two metals may be considered to have stood equally well.

In the next Series, 1—in atmospheric air—the differences became greater. The smallest loss was shown by the softest ingot iron ship plates, both annealed and unannealed, their loss being from 2·80 to 2·93 per cent. The ingot iron boiler plates lost 4·4 per cent., and the weld iron plates up to 4·6. A harder ingot iron ship plate lost between 3·45 and 3·95 per cent., so that in this instance also there is no very great difference between the behaviour of ingot iron and weld iron.

In the next Series, 5—alternately prepared sea water and atmospheric air—not taking into consideration the unannealed hardest ingot iron ship plate, the ingot metal rusted less than did the weld iron.

In Series 2—warm moist air—where the greatest differences were shown, it is remarkable that the spring steel rusted most, seeing that in boiler and feed water its degree of rusting was very slight indeed, and in atmospheric air, too, it resisted almost the best. Its loss in weight in Series 5 was from 7·91 to 8·43 per cent. Ingot iron boiler plate lost from 4·17 to 4·31 per cent., ingot iron ship plates from 4·35 to 6·45, and weld iron sheets from 5·65 to 7·30. In this rusting in warm moist air, therefore, the first marked difference between ingot iron and weld iron becomes noticeable. Ingot iron, on the whole, seems to resist rusting therefore better than does weld iron, a point which has often been thought not to be the case. If the annealed plates are examined among themselves, and the same is done for the unannealed plates, the results are somewhat different. In the unannealed series the ingot iron withstood rusting better than did the weld iron. In the annealed series the results were not so constantly in favour of the ingot iron, but still, on the whole, this latter metal had the advantage. With regard to the action of the manganese, carbon, and silicon as rust-inducing

elements, no decision could be arrived at, and it was impossible to say which of these elements had the greater action.

The author, in concluding, again draws attention to the changes in composition of steels which have taken place during the past fifteen years, which has seen the rise of the basic process. Both ingot metal and weld iron have greatly improved within the period in question. The curves, the author shows, are for experiments lasting each for the period of one thousand days, from October 1882 to May 1886. The following are the analyses of the metals examined in these tests:—

Metal.	Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.	Copper.
Ingot Iron—	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Boiler plate . .	0·06	0·004	0·15	0·13	0·04	0·13
Boiler plate . .	0·06	0·004	0·19	0·12	0·06	0·12
Ship plate . . .	0·07	0·009	0·27	0·12	0·04	0·12
Ship plate . . .	0·06	0·020	0·17	0·12	0·06	0·13
Ship plate . . .	0·15	0·020	0·59	0·11	0·05	0·12
Open-hearth Iron—						
Soft plate . . .	0·18	0·110	0·31	0·11	0·05	0·13
Spring steel . . .	0·38	0·260	0·29	0·09	0·04	0·13
Spring steel . . .	0·25	0·180	0·65	0·11	0·04	0·12
Weld Iron—						
Boiler plate . . .	0·07	0·080	0·15	0·10	0·008	0·06
Boiler plate . . .	0·06	0·070	0·15	0·14	0·010	0·05
Boiler plate . . .	0·09	0·090	0·15	0·18	0·015	0·06

Copper in Iron and Steel.—R. W. Raymond * summarises what is known of the effect of copper on iron and steel. In reply to B. F. Fackenthal, R. W. Hunt stated that copper is not considered in specifications for rails, because there is no evidence of its influence on the wear, although it is admitted that it tends to cause red-shortness. Dudley has made the same remarks, and this practice has been followed. It was formerly assumed that 0·4 per cent. of copper caused red-shortness in wrought iron; and Eggertz, in 1862, declared that its influence on steel was still greater. In 1882, Wasum showed that 0·20 to 0·30 carbon-steel would carry 0·059 per cent. of sulphur, and 0·452 of copper without red-shortness; and that steel with 0·06 sulphur and 0·862 copper, or 0·107 sulphur and 0·849 copper, gave but slight indications of red-shortness. Choubly showed that steels containing

P.	C.	S.	Mn.	Cu.
0·2	0·5 to 0·6	0·05 to 0·07	0·36 to 0·54	0·36 to 0·48

* *Transactions of the American Institute of Mining Engineers*, Colorado Meeting (advance proof).

were weldable at temperatures at and above red-heat. Hunt quotes the same author to show that steels may contain as much as 0·96 of copper without serious red-shortness; and W. W. Scranton habitually makes rails with 0·51 to 0·66 per cent. of copper. H. M. Howe describes some Holtzer steel at the Paris Exhibition containing 4 per cent. of copper, with high tensile strength and elastic limit.

CHEMICAL ANALYSIS.

CONTENTS.

I.—*ANALYSIS OF IRON AND STEEL.*

The Accuracy of Chemical Analysis.—F. P. Dewey * directs attention to the degree of accuracy exhibited in actual every-day practice of chemical analysis, and summarises the literature on this subject. As regards iron and steel, some of the results quoted are shown in the following table :—

Manganese in Steel.

Authority.	Date.	Number of Determinations.	Number of Chemists.	Percentage. Maximum.	Percentage. Minimum.	Percentage. Average.
W. Kent . . .	1881	24	10	1·14	0·303	0·415
A. E. Hunt . .	1886	...	...	...	...	...
G. C. Stone . .	1883–4	60	18	14·47	12·60	13·39
Phosphorus in Pig Iron.						
Potter and Riggs .	...	26	11	0·181	0·141	0·160
F. E. Bachman .	1882	44	18	0·165	0·069	0·143
G. Thackray . .	1895	36	23	0·055	0·045	0·0496
		8	2	0·033	0·012	...
		38	...	0·091	0·076	0·0835
Phosphoric Acid.						
Official Agricultural Chemists	1894	39	18	0·45	0·03	0·27
		36	19	0·34	0·04	0·19
		33	17	3·85	2·24	2·82
		35	17	3·49	2·18	2·83

* *Transactions of the American Institute of Mining Engineers;* Colorado Meeting (advance proof).

Other particulars relate to copper, gold and silver, and soils.

Within the past twenty years metallurgical practice has grown to depend more and more upon a chemical knowledge of the material employed in the various operations. On account of this dependence it has become necessary to have accurate, as well as rapid, methods for the determination of the elements which take an active part in the different processes. Many methods for the determination of the various elements usually met with in metallurgical work have been proposed, each having its own claim for accuracy or rapidity, or both; but, as will be seen from the efforts of the International Committee on the Analysis of Iron and Steel, perfect methods for metallurgical analysis are not yet available. There are many sources of error in ordinary quantitative determinations, which, while they can be partially avoided, can never be wholly overcome. Among these may be mentioned such errors as arise from solubility of precipitates, solubility of apparatus in which operations are performed, impurities in chemicals, inaccurate graduation of volumetric apparatus, unavoidable error in accuracy of weighing, and last, but not least, errors due to what may be called the personal equation, the presence or absence in the operator of that manipulative skill which distinguishes an expert from a clumsy worker. Since absolute agreement in results cannot be expected, it may be asked how closely should quantitative determinations agree. This question cannot be answered by a single figure, since the unavoidable errors in the various determinations differ according to the element determined and the method used in the analysis. Just how great a difference between determinations should be allowed, and what the probable limit of accuracy which may be hoped for, is largely a matter of judgment, based upon the examination of the results obtained by different chemists working upon the same material. Basing his judgment upon the usual errors of analysis, upon the commercial requirements of accuracy, and upon the unavoidable sources of error, E. D. Campbell * proposes the following schedule of allowable differences and of probable limits of accuracy for discussion in the section. In the table below, the first column shows the element or constituent determined; the second, a formula for calculating the difference which might be reasonably expected between the results of two chemists working upon the same material; and the third column shows a formula for calculating the probable minimum error which

* *Proceedings of the American Association for the Advancement of Science*, vol. xliv. pp. 98–100.

may be hoped for. To take an instance: Suppose chemist A reports the phosphorus in a specimen of steel as 0·076 per cent., then by the formula in the table we might expect B to report $0·076 \pm 0·00352$ per cent., and from the third column we could not hope to reduce the error to less than 0·00058 per cent.

Element or Constituent.	Allowance Difference of, per Cent.	Probable Limit of Accuracy.
Iron and Steel—		
Graphitic carbon	$\pm\{0·050 + (0·02 \times Cg)\}$	$\pm\{0·005 + (0·005 \times Cg)\}$
Cast iron / Combined carbon	$\pm\{0·050 + (0·02 \times Cc)\}$	$\pm\{0·005 + (0·005 \times Cc)\}$
Carbon in steel	$\pm\{0·010 + (0·02 \times C)\}$	$\pm\{0·002 + (0·003 \times C)\}$
Silicon, Si	$\pm\{0·005 + (0·02 \times Si)\}$	$\pm\{0·002 + (0·003 \times Si)\}$
Sulphur, S	$\pm\{0·003 + (0·03 \times S)\}$	$\pm\{0·0005 + (0·005 \times S)\}$
Phosphorus, P	$\pm\{0·002 + (0·02 \times P)\}$	$\pm\{0·0002 + (0·005 \times P)\}$
Manganese, Mn, in cast iron and steel	$\pm\{0·005 + (0·04 \times Mn)\}$	$\pm\{0·001 + (0·005 \times Mn)\}$
Manganese, Mn, in spiegels, ferro, &c.	$\pm\{0·050 + (0·004 \times Mn)\}$	$\pm\{0·005 + (0·001 \times Mn)\}$
Nickel, Ni	$\pm\{0·050 + (0·02 \times Ni)\}$	$\pm\{0·005 + (0·005 \times Ni)\}$
Analysis of Ores—		
Silica, SiO_2	$\pm\{0·050 + (0·006 \times SiO_2)\}$	$\pm\{0·005 + (0·001 \times SiO_2)\}$
Alumina, Al_2O_3	$\pm\{0·030 + (0·003 \times Al_2O_3)\}$	$\pm\{0·005 + (0·001 \times Al_2O_3)\}$
Ferric-oxide, Fe_2O_3	$\pm\{0·030 + (0·003 \times Fe_2O_3)\}$	$\pm\{0·005 + (0·001 \times Fe_2O_3)\}$
Iron, Fe	$\pm\{0·020 + (0·003 \times Fe)\}$	$\pm\{0·004 + (0·001 \times Fe)\}$
Manganese, Mn	$\pm\{0·050 + (0·002 \times Mn)\}$	$\pm\{0·005 + (0·001 \times Mn)\}$
Calcium-oxide, CaO	$\pm\{0·050 + (0·002 \times CaO)\}$	$\pm\{0·010 + (0·001 \times CaO)\}$
Magnesia, MgO	$\pm\{0·050 + (0·010 \times MgO)\}$	$\pm\{0·005 + (0·002 \times MgO)\}$
Phosphorus, P	$\pm\{0·002 + (0·02 \times P)\}$	$\pm\{0·0002 + (0·005 \times P)\}$
Phosphorus - pentoxide, P_2O_5	$\pm\{0·005 + (0·02 \times P_2O_5)\}$	$\pm\{0·0005 + (0·005 \times P_2O_5)\}$
Combined water	$\pm\{0·050 + (0·010 \times H_2O)\}$	$\pm\{0·010 + (0·001 \times H_2O)\}$
Potassium-oxide, K_2O / Sodium oxide, Na_2O	$\pm\{0·050 + (0·020 \times K_2O)\}$	$\pm\{0·005 + (0·005 \times K_2O)\}$
Sulphur, S, in iron ore	$\pm\{0·005 + (0·030 \times S)\}$	$\pm\{0·001 + (0·003 \times S)\}$
Sulphur in pyrite	$\pm\{0·050 + (0·004 \times S)\}$	$\pm\{0·005 + (0·0002 \times S)\}$
Lead, Pb	$\pm\{0·050 + (0·003 \times Pb)\}$	$\pm\{0·005 + (0·0005 \times Pb)\}$
Zinc, Zn	$\pm\{0·050 + (0·003 \times Zn)\}$	$\pm\{0·005 + (0·0005 \times Zn)\}$
Copper, Cu	$\pm\{0·030 + (0·003 \times Cu)\}$	$\pm\{0·005 + (0·001 \times Cu)\}$
Nickel, Ni	$\pm\{0·030 + (0·003 \times Ni)\}$	$\pm\{0·005 + (0·001 \times Ni)\}$
Arsenic, As / Antimony, Sb	$\pm\{0·050 + (0·010 \times As)\}$	$\pm\{0·002 + (0·001 \times As)\}$
Tin, Sn	$\pm\{0·010 + (0·010 \times Sn)\}$	$\{0·005 + (0·001 \times Sn)\}$
Coal and Coke—		
Moisture	$\pm\{0·050 + (0·020 \times H_2O)\}$	$\pm\{0·005 + (0·005 \times H_2O)\}$
Volatile hydrocarbons	$\pm\{0·050 + (0·010 \times hydro)\}$	$\pm\{0·010 + (0·001 \times hydro)\}$
Fixed carbon	$\pm\{0·050 + (0·010 \times C)\}$	$\pm\{0·010 + (0·001 \times C)\}$
Sulphur, S	$\pm\{0·020 + (0·030 \times S)\}$	$\pm\{0·005 + (0·003 \times S)\}$
Ash	$\pm\{0·050 + (0·005 \times Ash)\}$	$\pm\{0·005 + (0·001 \times Ash)\}$
Phosphorus	$\pm\{0·002 + (0·02 \times P)\}$	$\pm\{0·0002 + (0·005 \times P)\}$

B. Neumann * gives, in tabular form, details showing the degree of sensitiveness of various indicators. No such table previously existed, and in addition to information previously published and found scattered through technical literature, the author has himself made a number of determinations. Among these are the following:—

For Ferric Oxide.

Reagent.	Degrees of Sensitiveness.	Observer.
Potassium ferrocyanide	1 : 500,000	Wagner.
Potassium sulphocyanide	1 : 1,600,000	,,
Ammonia	1 : 800,000	...
Ammonia and thioglycolic acid	1 : 200,000	Andreasch.
Campeche wood extract	1 : 15,000,000	Bellamy.
Tannin	1 : 300,000	Wagner.
Salicylic acid	1 : 32,000	Smith.
Salicylic acid	1 : 100,000	Almen.
Ammonium sulphide	1 : 2,000	Mylius.
Sodium sulphide	1 : 700,000	...

For Ferrous Oxide.

Potassium ferricyanide	1 : 440,000	...
Ammonia	1 : 500,000	...
Oxalic acid	1 : 5,000	...
Sulphuric acid and nitric acid	1 : 300,000	Warington.
Tannin	1 : 440,000	...
Sodium sulphide	1 : 700,000	...

For Manganese.

Silver nitrate and caustic soda	1 : 200,000	...
Hydrogen peroxide	1 : 200,000	Klein.
Potassium ferrocyanide	1 : 25,000	Blum.
Ammonia	1 : 100,000	...
Sodium sulphide	1 : 500,000	...

For Nickel.

Potassium xanthogenate	1 : 100,000	Braun.
Bromine and caustic potash	1 : 1,000,000	...
Potassium ferrocyanide	1 : 100,000	...
Ammonia	1 : 10,000	...
Sodium sulphide	1 : 1,000,000	...
Caustic soda	1 : 10,000	...

* *Chemiker Zeitung*, vol. xx. pp. 763–764.

Irregularity in the Composition of Samples.—Baron H. von Jüptner * considers the question as to how far differences in analyses are due to irregularities in the composition of the samples examined. It is one of the chief causes, he points out, and makes itself felt in various ways. Liquation phenomena affect it in practice, and he quotes Snelus' well-known experiments in proof of this, and others of Eccles. Even portions which immediately adjoin each other vary greatly in composition. That this is the case for carbon every one knows, but other elements behave in a similar way. The different results of determinations of phosphorus in one and the same pig iron made by eight analysts differed so much, that the maximum result was about double the minimum. In another pig iron sixteen analysts obtained results for sulphur which varied from 0·005 to 0·024 per cent., and the very highest and lowest results were obtained by analysts of good repute. In the case of steel, too, such differences in the sulphur occurs, as the author shows by the results of sixteen samples taken from a piece of metal 30 millimetres wide and 6 thick, high enough in sulphur to enable small samples to be adequate for the determination. These were taken in a regular manner, in a way the author shows by means of illustrations. The metal was ruled into oblongs, each oblong representing a sample. No. V. contained 0·093 per cent. of sulphur; Nos. IX., X., VI., II., and I., by which it was bounded, contained respectively 0·056, 0·060, 0·072, 0·082, and 0·092 per cent. The lowest result obtained was 0·037 per cent., and the highest 0·097 per cent. By shading differently the oblongs in which approximately similar percentages of sulphur existed, the author shows this separation clearly. The separation appears to run in bands in the direction of the longest axis of the metal. Double samples were taken in each case to show that the differences were not due to any errors of analysis. In sampling, the more brittle the metal the smaller will be the drillings, and consequently extreme care must be taken to thoroughly mix any large quantity before taking smaller samples from it. The author quotes the results of L. Schneider † in proof of this.

The Atomic Weights of the Elements.—Baron H. von Jüptner ‡ publishes a table showing the various atomic weights which have been

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 159–161.
† *Journal of the Iron and Steel Institute*, 1894, No. II., pp. 488–489.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 254–256.

proposed for the different elements. Among these the variations are as follows for the elements named :—

Iron	55·8800 to 56·000
Manganese	53·9060 ,, 55·000
Carbon	11·9736 ,, 12·005
Silicon	28·0000 ,, 28·400
Sulphur	31·9840 ,, 32·060
Phosphorus	30·9500 ,, 30·960
Chromium	52·0090 ,, 52·450
Nickel	57·9280 ,, 58·700

The higher numbers are in most instances more recent than the lower ones. For aluminium the variation is from 27·009 to 27·08; for arsenic, from 74·9 to 75; for lead, from 206·39 to 206·95; for copper, from 63·173 to 63·6; for titanium, from 48 to 50·25 (the lowest number being Clarke's 1893 calculation); and for tungsten, from 183·6 to 184.

The Analysis of Iron.—A. A. Blair* has published the third edition of his treatise on the chemical analysis of iron. The work gives a complete account of all the best known methods for the analysis of iron, steel, pig iron, iron ore, limestone, clay, sand, coal, coke, and furnace and producer gases. In the third edition several important additions, and such minor changes as were necessary to bring the methods described in accord with the recent progress of science, have been made.

Determination of Carbon.—In the apparatus devised by A. A. Blair,† a 400 cubic centimetre pipette is connected by means of stopcocks with a burette, and by lowering the mercury reservoir the pipette is filled with aqueous potash of specific gravity 1·27. The burette is filled with mercury, and one gramme of the steel drillings is introduced into a 200 cubic centimetre flask, which is then attached to the apparatus. The water is started through the condenser, and the flask is connected with the burette; 15 cubic centimetres of a saturated solution of pure copper sulphate is poured through a funnel tube into the flask. After it has acted long enough to form a superficial deposit of copper on the metal, 15 cubic centimetres of a 50 per cent. solution

* "The Chemical Analysis of Iron." Third edition. Philadelphia: J. B. Lippincott Company, 1869. A copy of this work has been presented by the author to the Library of the Institute.

† *Journal of the American Chemical Society*, vol. xviii. pp. 223–227; *Journal of the Chemical Society*, vol. lxx. p. 544.

of chromic acid and 135 cubic centimetres of the following mixture is added :—35 cubic centimetres of chromic acid solution, 115 cubic centimetres of water, 750 cubic centimetres of sulphuric acid, and 315 cubic centimetres of phosphoric acid of 1·4 specific gravity. The solution in the flask is now raised to the boiling point, and, by means of the reservoir, the mercury in the burette and the tube is kept nearly level. The water condensed drops back into the flask, and keeps the liquid of the same density, while the cooled gases pass into the burette. The flask is now allowed to cool for five minutes, and is then filled with water, thus forcing all the gas into the burette. The cock is then closed, and the burette is connected with a manometer containing water; the levels are adjusted accurately, and the reading of the burette is taken.

The burette is connected with the pipette, and by raising and lowering the reservoir the gas is passed several times backwards and forwards to cause the alkali to absorb all the carbonic anhydride. Another reading is then made, care being taken that the burette contains a few drops of water, and the difference between the two readings represents the volume of the carbonic anhydride, which is then corrected for pressure, temperature, and moisture. The volume of the gas so obtained, multiplied by 0·0019663, gives the weight.

Determination of Phosphorus.—C. Fairbanks* describes an iodometric method for the determination of phosphorus in iron, and gives a table showing satisfactory results obtained.

H. K. Landis † discusses the methods described by G. E. Thackray.‡ The results by different methods are classified, and the probable error calculated by the method of squares. Emmerton's and the acetate methods give smaller probable errors as the amount of phosphorus increases, and so are more accurate. It is also concluded that Emmerton's phosphorus factor is right, that it is not necessary to have enough MoO_3 present to form iron molybdate with all the iron and leave an excess after deducting enough to combine with the phosphorus, and also that it is advisable to nearly neutralise before precipitation.

According to G. Auchy, § the sources of error in Volhard's process are :—

* *American Journal of Science*, vol. ii. pp. 181–185.

† *Transactions of the American Institute of Mining Engineers;* Colorado Meeting (advance proof).

‡ *Journal of the Iron and Steel Institute*, 1895, No. II. p. 590.

§ *Journal of the American Chemical Society*, vol. xviii. p. 498.

1. The incomplete neutralisation by zinc oxide, giving usually high results.

2. The too sudden addition of the necessary excess of zinc oxide, giving frequently low results.

3. The titration in nitric acid solution, giving results 0·01 or 0·02 per cent. too high.

4. Neutralisation by zinc oxide in hot solution, giving high results.

Determination of Manganese.—F. Ulzer * and J. Brüll mention the various methods which have been proposed for the determination of manganese in pig iron. They recommend the following as being the best method:—Following Volhard's method, the solution of manganese freed from iron oxide by the aid of oxide of zinc, and containing about 0·1 gramme of manganese, has added to it about 20 cubic centimetres of a 5 per cent. solution of hydrogen peroxide, and caustic soda is added as long as a precipitate is produced. It is then boiled, allowed to cool, and a standardised solution of oxalic acid is added until the precipitate has dissolved. After the solution has been effected, the whole is brought nearly to a boil, and the remaining excess of oxalic acid is titrated back again with permanganate solution. Knowing the quantity of oxalic acid used, the percentage of manganese is readily calculated, it being remembered, however, that the manganese precipitate had the composition $5MnO_2$, MnO_7. To effect the solution of the iron samples the authors used the acid mixture suggested by Weissmann, which consists of 10 volumes of concentrated nitric acid mixed with 2 of concentrated sulphuric acid and 10 of water. During the evaporation about 10 cubic centimetres of concentrated hydrochloric acid was also added.

G. Auchy † uses Volhard's volumetric process for estimating manganese in samples of steel, but in order to get trustworthy results the following details should be adhered to:—3·3 grammes of the sample is dissolved in a covered evaporating dish in 40 cubic centimetres of 50 per cent. nitric acid, and 8 cubic centimetres of strong sulphuric acid is then added. If, on evaporating, there is a tendency to bumping or spattering, some hydrochloric acid should be added. When the mass becomes pasty and nearly dry it is allowed to slightly cool, and is then boiled with water for a few minutes. When cold the liquid is

* *Mittheilungen technolog. Gewerbe-Museum, Vienna*, 1895, vol. v. p. 312; *Stahl und Eisen*, vol. xvi. p. 633.

† *Journal of the American Chemical Society*, vol. xvii. pp. 343–347.

introduced into a 500 cubic centimetre flask, nearly neutralised with sodium carbonate, and the iron precipitated by adding a sufficiency of emulsion of zinc oxide. After diluting to the mark and filtering, 250 cubic centimetres of the filtrate is boiled in a 500 cubic centimetre Erlenmayer flask and titrated with standard permanganate (strength, 0·0055) until the supernatant liquid turns a rose colour, no longer changing to yellow after shaking well. If the percentage of manganese is approximately known, it is better to add the greater part of the permanganate at once. The number of cubic centimetres of permanganate, divided by ten, equals the percentage of manganese in the sample.

G. C. Stone * thinks that Volhard's method, as modified by Auchy, is unnecessarily complicated, and states that the process gives very accurate results if used as follows:—The quantity of manganese should amount to from 0·05 to 0·15 gramme. The sample of iron is dissolved in a suitable acid, but care must be taken to thoroughly oxidise the iron by boiling with nitric acid, or with hydrochloric acid and potassium chlorate. After cooling, the solution is mixed with a sufficiency of an emulsion of zinc oxide, and then made up to exactly 500 cubic centimetres. When the precipitate has subsided, 100 cubic centimetres of the liquid is put into a basin, diluted to 200 cubic centimetres, heated to boiling, and rapidly titrated with standard permanganate while vigorously stirred.

Determination of Sulphur.—F. C. Phillips † shows that when hydrochloric acid acts on iron rich in carbon, by no means the whole of the sulphur is liberated in the form of hydrogen sulphide, much is in the form of organic compounds, which are only attacked with difficulty by oxidising agents. In the escaping gases methyl-mercaptan and methyl-sulphide could be easily recognised. The author proposes the following method for the determination of the sulphur to prevent loss:—Hydrochloric acid of 1·12 specific gravity is slowly added to the iron, a current of carbon dioxide being simultaneously passed through the solution. The gases evolved are passed through a red-hot porcelain tube, in which platinum is charged in such a way as to bring it right up to the tube connecting with the dissolving flask. The iron solution is boiled slowly for from 2 to 2·5 hours. The gases escaping from the porcelain tube are passed through a solution

* *Journal of the American Chemical Society*, vol. xviii. pp. 228–229.
† *Ibid.*, vol. xvii. pp. 891-900.

of bromine in dilute hydrochloric acid, and then into a vessel of about eight litres capacity, which also contains a little of this bromine solution. Experiments show that a large absorption vessel is absolutely necessary. It is subsequently determined as barium sulphate. Instead of the platinum, mica could be used, but this would be rapidly attacked by the hot acid vapours.

G. G. Boucher * dissolves 5 grammes of iron or steel in a strong solution of copper-ammonium chloride, and when the precipitated copper is dissolved, the solution is filtered. The filter-paper and contents are then thoroughly washed with hot distilled water till the washings are free from copper. The sulphur remains on the paper with the graphite and a small quantity of silica and iron. The paper and contents are now placed in a small beaker, and about 30 cubic centimetres of nitro-hydrochloric acid are added; the solution is then boiled and filtered; the filtrate is neutralised with ammonium hydrate, and then made slightly acid with dilute hydrochloric acid. To the solution 5 grammes of barium chloride are now added; the solution is heated, and the barium sulphate allowed to settle. It is then filtered off, well washed, burnt, and weighed.

Instead of dissolving the sulphur out of the residue of graphite, &c., with nitro-hydrochloric acid, the paper and contents may be boiled with bromine water and a few drops of hydrochloric acid. When the excess of bromine has been boiled off, the solution is filtered, and barium chloride added to the filtrate. The solution is heated, &c., as before. The following are some of the results obtained :—

	Nitro-Hydrochloric Acid Method.	Copper-Ammonium Chloride Method.	
	Sulphur, per Cent.	Sulphur, per Cent.	
1. Bessemer iron	0·035	0·041	
2. Do. do.	0·012	0·021	
3. Do. do.	0·022	0·024	
4. Do. do.	0·023	0·023	
		1st. Anal.	2nd Anal.
5. Do. do.	...	0·020	0·021
6. Mottled iron	0·185	0·192	0·192

This process is particularly adapted for the estimation of small quantities of sulphur, the absence of a large quantity of ferric-chloride and free hydrochloric acid, in which barium sulphate is soluble to an appreciable extent, rendering the process extremely accurate. The percent-

* *The Chemical News*, vol. lxxiv. p. 76.

age of sulphur obtained by this process is higher than that given by any other process, and the barium sulphate is always white, showing the absence of iron.

G. Auchy * has slightly modified Drown's method of estimating sulphur in pig iron. His method of procedure is as follows:—3·4335 grammes of the pig iron drillings is introduced into a 16-ounce flask connected with a Troilius' bulb, containing 6 cubic centimetres of a 1 per cent. solution of potassium permanganate and 6 cubic centimetres of 20 per cent. aqueous potash. The iron is dissolved in hot dilute hydrochloric acid, and finally air is drawn through the apparatus by means of a filter pump. The contents of the bulb are washed into a small beaker. The iron solution is filtered, and after being washed, the insoluble residue is rinsed into an evaporating dish. After evaporating to dryness, 30 cubic centimetres of nitro-hydrochloric acid is added, and then again evaporated off. The mass is heated with 10 cubic centimetres of dilute hydrochloric acid, which is then filtered and added to the alkaline permanganate solution, which, of course, contains the greater part of the sulphur. To better reduce the excess of permanganate, a sufficiency of oxalic acid is added, and the liquid is boiled. The sulphuric acid is then precipitated in the usual way with barium chloride. Traces of silica in the potash, or a little undecomposed oxalic acid, do not in the least interfere.

Determination of Chromium.—S. Rideal and S. Rosenblum † have continued their examination of the sodium peroxide method for the analysis of chrome iron ore and alloys.‡ After critically examining the methods already proposed, they conclude that the best results are to be obtained as follows:—0·3 to 0·7 gramme (according to the probable percentage of chromium) of the finely powdered chrome iron ore, or ferrochromium, is mixed in a nickel crucible with six times its weight of sodium peroxide, and the crucible then heated very gently, until the mass begins to melt, and then to glow by itself. The heating is then continued for about ten minutes, a circular movement being given to the crucible from time to time, and after the mass has partially cooled, about 1 gramme more of sodium peroxide is added, and the heating then continued for another 3 to 5 minutes. The crucible, when still moderately warm, is put into a porcelain beaker, and covered with hot

* *Journal of the American Chemical Society*, vol. xviii. pp. 406–411.

† *Journal of the Society of Chemical Industry*, vol. xiv. p. 1017.

‡ *Journal of the Iron and Steel Institute*, 1895, No. II. p. 158. (Discussion on Mr. Saniter's Paper.)

water; the fused mass dissolves very rapidly, and with considerable effervescence. After the solution is complete the crucible is taken out, and about 0·5 gramme of sodium peroxide added in order to decompose in the solution of the melt any sodium ferrate and manganate which have formed during the fusion, especially in the case of ferro-chromium. The solution is then boiled briskly for about ten minutes, after which all excess of sodium peroxide will be found to be completely decomposed, allowed to settle, and the precipitate, consisting of oxides of nickel, iron and manganese, filtered off, and washed until the wash-water passing through the filter is quite colourless. The filtrate is acidified with dilute sulphuric acid, boiled to drive off any carbonic acid due to the presence of sodium carbonate in the sodium-peroxide used, cooled and titrated in the usual manner with ferrous ammonium sulphate.

This method excludes all sources of error arising from the presence of undecomposed sodium peroxide, sodium ferrate, sodium manganate, or nickel salts, and, as the authors show by numerous analyses, gives very exact and accordant results.

Later papers on the same subject have been published by E. Waller * and by H. A. Brustlein; † and S. Rideal and S. Rosenblum ‡ have published a complete bibliography of this subject from 1852.

II.—*ANALYSIS OF IRON ORES AND SLAGS.*

Determination of Iron.—Baron H. von Jüptner § gives additional details relating to the standardising of permanganate solution used in the determination of iron. He deals with Lunge's method with hydrogen peroxide in his "Universal Gas Volumeter." This method has the great advantage over all others, that it is entirely independent of the purity of the original substance. It is so easy of manipulation too, and so rapid, that it is quite on a level in this direction with the ferrous ammonium sulphate and oxalic acid, if indeed it does not even exceed it. The method depends on the reaction $K_2Mn_2O_8 + 5H_2O_2$

* *Journal of the Society of Chemical Industry*, vol. xv. pp. 436–437.

† *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 409–426. A reprint of this paper has been presented by the author to the Institute library.

‡ *Chemical News*, vol. lxxiii. p. 1.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 371–373, one illustration.

$+ 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 8H_2O + O_{10}$. One-half of the oxygen thus liberated represents the decomposed permanganic acid, and the other the hydrogen peroxide. As, however, 1 cubic centimetre of oxygen at normal pressure and temperature at Berlin (lat. 50° 31′ 13″, and 134 ft. 6 in. above sea-level) weighs 0·00143003 gramme, one-half of this represents the iron, that is, from 0·00250250 to 0·00250436 gramme of iron, according to one or other of the published atomic weights of iron that is taken as the basis of the calculation.

The Lunge apparatus used is described by the author with the aid of an illustration, and the method of using it is also given. Comparative standardising tests made by the oxalic acid method and this hydrogen peroxide method gave the following results:—

Oxalic Acid Method.	Hydrogen Peroxide, 10 c.c. Permanganate.	Hydrogen Peroxide, 20 c.c. Permanganate.
0·000171	0·00018013	0·00017040
0·000177	0·00017134	0·00017622
0·000168	0·00016839	0·00017157
0·000172	0·00017074	0·00017191
0·000172	0·00017200	0·00017228
Average.	Average.	Average.
0·0001720	0·00017252	0·00017245
0·000093	0·00009613	0·00009613
0·000089	0·00009439	0·00009439
0·000097	0·00009688	0·00009688
0·000096	0·00009207	0·00009207
0·000090	0·00009009	0·00009009
Average.	Average.	Average.
0·0000930	0·00009284	0·000093912

The readings with Lunge's apparatus are accurate to 0·1 cubic centimetre, and the possible error per cubic centimetre of permanganate is as follows, according to whether 10 cubic centimetres or 20 cubic centimetres are used:—

Disposable oxygen . .	0·00001430	to 0·00000715	gramme.
Iron, 55·913 atomic weight .	0·00002504	,, 0·00001252	,,
,, 55·88 ,, . .	0·00002503	,, 0·00001252	,,
,, 56·0 ,, . .	0·00002502	,, 0·00001251	,,

H. H. Nicholson and S. Avery * found that a slight modification of Classen's electrolytic method greatly facilitated the precipitation of iron. The following procedure gave satisfactory results:—Twenty-five cubic centimetres of a solution of ferrous sulphate was taken, 5 grammes

* *Zeitschrift für anorganische Chemie*, 1896, p. 1291.

of ammonium oxalate was added, and brought into solution by the aid of gentle heat. Five cubic centimetres of a saturated solution of borax was now added, and the entire solution diluted to 150 cubic centimetres. A current of 0·02 ampère was allowed to act on the cold solution for sixteen hours. Towards the end of the operation the anode became covered with a slight brown coating. A slight brown deposit also appeared on the dish above the iron deposit. The following method was used to dissolve these deposits. Water was added until the surface of the liquid was raised above the brown deposit in the dish. The positive electrode was then brought in contact for a moment with the side of the dish, thus short-circuiting the battery and generating considerable heat in the electrodes. This had the effect of liberating and dissolving the brown deposit. The current was allowed to act for half-an-hour longer, when the dish was removed from the circuit, washed, dried, and weighed.

The precipitate was perfectly adherent, and showed no tendency to oxidise when washed with alcohol and ether. The following is a tabular statement of the results obtained:—

No.	Ammonium Oxalate.	Saturated Borax Solution.	Current.	Time.	Iron Taken.	Iron Found.
	Grammes.	C.c.	Ampère.	Hours.	Gramme.	Gramme.
1	5	5	0·02	16	0·0938	0·0933
2	5	10	0·02	17	0·0938	0 0935
3	6	10	0·06	4	0·0938	0·0938
4	5	5	0·072	2	0·0938	0·0939
5	6	5	0·125	2	0·0938	0·0938

It will be seen from the above that the presence of borax facilitates the precipitation of iron in ammonium oxalate solutions. The cause of the appearance of the slight brown deposit, and the extent to which it might cause an error in results, will be investigated later.

Determination of Manganese.—Särnström's method of estimating manganese in iron ores is based on the well-known fact that manganese is not precipitated from strongly acid solutions by sodium carbonate, whilst iron is readily thrown down. C. T. Mixer and H. W. Du Bois * find that in the case of ores poor in manganese the process gives excellent results if care is taken to avoid excess of sodium carbonate. The use of the bicarbonate has no practical advantage. After the iron

* *Journal of the American Chemical Society*, vol. xviii. pp. 385–389.

hydroxide has subsided, the liquid is at once warmed to 80° C., and titrated with standard permanganate. For ores rich in manganese, the method is untrustworthy.

Volumetric Determination of Titanic Anhydride.—H. L. Wells and W. L. Mitchell * heat 5 grammes of the powdered ore with 100 cubic centimetres (or more) of strong hydrochloric acid. When action ceases, 50 cubic centimetres of dilute sulphuric acid (50 per cent. by volume) is added, and the liquid evaporated until sulphuric acid fumes make their appearance. When cold, 200 cubic centimetres of water is added, and as soon as the sulphates have dissolved, the liquid is filtered into a litre flask; any insoluble matter must be fused with potassium hydrogen sulphate, and the solution of the melt added to the main liquid. The liquid is now made up to the mark, and 200 cubic centimetres (1 gramme of the sample) is reduced by hydrogen sulphide; when quite reduced the liquid is boiled to expel the gas, and to avoid contact with air the flask is covered with a crucible lid. After filling up to the mark with recently boiled water, the contents of the flask are rapidly cooled, transferred to a large beaker, and titrated with permanganate; the precipitated sulphur has no action on the permanganate. The titration is of course repeated. Another 200 cubic centimetres is mixed in a 500 cubic centimetres Erlenmeyer flask, with 25 cubic centimetres of sulphuric acid, and three or four rods of pure zinc suspended from a platinum wire are introduced; after boiling 30 to 40 minutes, a rapid current of carbonic anhydride is passed through, and the contents rapidly cooled. The zinc is now removed, and the solution titrated with permanganate, while the carbonic anhydride is still passing. The difference in the two titrations represents the titanic acid. The factor for metallic iron, divided by 0·7, is the one for titanic anhydride.

Determination of Alkalies.—C. Reinhardt † considers the determination of alkalies in refractory materials. Theoretically, he observes, this is not difficult, but in practice many difficulties are experienced, with the result that percentages of alkalies may be found as a result of the analysis which cannot possibly have been present in the material examined. The method he adopts is as follows:—3 grammes of the finely powdered material is taken, after having carefully dried this for

* *Journal of the American Chemical Society*, vol. xvii. pp. 878–885.
† *Stahl und Eisen*, vol. xvi. pp. 448–452.

about an hour at a temperature of from 100° to 110° C. It is then changed into a platinum dish, 80 millimetres in diameter and 50 deep, flat-bottomed, and provided with a cover. Ten cubic centimetres of water is charged into this before the dried material is added, and it is next treated with 40 cubic centimetres of the purest fuming hydrofluoric acid, and 5 of the purest possible sulphuric acid, of the specific gravity 1·84. Keeping the dish covered, it is heated in the usual way until decomposed. This takes from 15 to 30 minutes. The cover is then removed, washed down, and the solution evaporated at not too high a temperature, the flame being diminished towards the termination of the evaporation to avoid spitting. In the case of materials which give rise to a rapid evolution of gas in this evaporation the dish must be kept covered, and it must be heated until vapours of sulphuric acid begin to be given off.

The whole is then heated more strongly until the fumes of sulphuric acid have entirely ceased. Free sulphuric acid is then nearly entirely eliminated. This is absolutely necessary, as otherwise large quantities of ammonium sulphate would be formed, which would give rise to difficulties through spitting on evaporation. It requires about three hours to dissolve the sample and to get rid of the sulphuric acid. By heating the substance with hydrofluoric acid and sulphuric acid, silica and boric acid are eliminated, as is shown by the reactions

$$SiO_2 + 4HFl = SiFl_4 + 2H_2O$$
$$B_2O_3 + 6HFl = 2BFl_3 + 3H_2O.$$

After completely driving off the sulphuric acid the contents of the dish is cooled, dissolved in 50 cubic centimetres of water by heating gently for some time and stirring with a thick platinum wire. Most passes into solution, with the exception of a slimy residue, which contains small quantities of silica and alumina, the whole of the barium, and a portion of the lime as sulphate. The whole is then transferred carefully to a 300 cubic centimetre flask, a few drops of rosolic acid is added—1 gramme of rosolic acid and 250 cubic centimetres of water, and 250 of 96 per cent. alcohol. It is then diluted with water until the flask is about three parts full, and heated, shaking occasionally, until it boils. A 10 per cent. solution of ammonia is then added drop by drop from a 10 cubic centimetre measure, until a red coloration shows alkalinity; 3 cubic centimetres of the purest hydrogen peroxide is then added for the oxidation of any ferrous oxide and for manganese. The contents of the flask is then heated for some time, allowed to get quite cold, filled up to the mark, and thoroughly mixed. The whole is then

filtered through two large dry filters that have been thoroughly washed with hydrochloric acid, and 100 cubic centimetres of the filtrate is evaporated in a platinum dish, while a second hundred is filtering through. This second hundred cubic centimetres is added to the first, and the whole evaporated to dryness on an asbestos sheet. Towards the end of the evaporation, when the quantity of solution has been reduced to about 10 or 20 cubic centimetres, the flame must be made much smaller, and constant attention must subsequently be paid to the evaporation. As soon as bubbles begin to form, the contents of the dish must be kept stirred by a platinum wire. The evaporation is continued until the mass has balled together and become thoroughly dry. The temperature is subsequently gradually raised to redness, ammonium sulphate vapours being then freely evolved. When these have ceased the cover is removed, and the dish kept at dull redness for some time longer, the cover being also similarly heated. The dish is then allowed to cool, washed down with a little hot water, 5 cubic centimetres sulphuric acid of one-fourth strength added, together with a little hydrofluoric acid, and heated as before, the heating being subsequently continued until the dry mass has reached redness. The sulphuric acid is thus eliminated, and any organic matter destroyed. After cooling, 10 cubic centimetres of hydrochloric acid of 1·19 specific gravity is added, and the residue dissolved by heating gently. After nearly evaporating, 20 cubic centimetres of water is added, the whole raised nearly to boiling, some 10 per cent. ammonia added until the reaction is alkaline, heated, filtered hot through two dry ash-free filters into a smaller beaker, washed, the filtrate heated until it nearly boils, 2 cubic centimetres of a clear, freshly prepared ammonium oxalate solution added, heated for a while longer, and then allowed to cool down. In a few hours the lime precipitate can be filtered off, when the filtrate, which contains MgO,Na_2O,K_2O, is evaporated to dryness, heated to redness, dissolved in water, filtered into a platinum crucible, 3 cubic centimetres of sulphuric acid added, evaporated, and heated till sulphuric acid fumes cease. After cooling, a small piece of pure ammonium carbonate is added, and the whole again heated to dull redness. Neutral sulphates then result, the residue consisting of $MgSO_4 + K_2SO_4 + Na_2SO_4$, resulting from 2 grammes of the substance treated together with that from the materials used, the quantity derived from which source being separately determined by a blank experiment.

If it is only a question of determining the total alkalies, which is

all that is usually necessary, the residue is weighed, dissolved in water, and diluted to 200 cubic centimetres. One half of this is placed in a beaker, a few drops of rosolic acid added, then 10 cubic centimetres of 50 per cent. hydrochloric acid, and 10 per cent. ammonia until the solution is alkaline, when 30 cubic centimetres of this dilute ammonia is added in excess. After completely cooling, the magnesia is precipitated by the addition of 0·5 gramme of the purest sodium di-phosphate dissolved in a little hot water, the precipitation being effected much in the ordinary way, though with considerable care. That portion of the precipitate, however, which adheres to the glass is redissolved with a little nitric acid, and is subsequently brought with the remainder of the precipitate to a red heat in a platinum crucible, and the contents weighed as $Mg_2P_2O_7$.

A second portion of the solution, 75 cubic centimetres in quantity, is treated with barium chloride for the determination of the sulphuric acid, and this and the magnesia having thus been found, the balance represents the alkalies present. The author gives full details again for the blank test, which is absolutely necessary.

A. Cameron * has proved by several experiments that the barium hydroxide process is thoroughly trustworthy for the estimation of alkalies in manures, even in the presence of magnesia. The sulphate and carbonate methods may also be successfully employed, but the chloride method, on account of its troublesome nature and untrustworthy results, cannot be recommended.

Determination of Zinc.—It is pointed out by Kinder † that zinc is of frequent occurrence in iron ores, and especially in those that are manganiferous. Frequently, however, only a few tenths per cent. are present, a quantity which is often overlooked with the ordinary methods of analysis. The Hampe method for the separation of the zinc from the iron by means of hydrogen sulphide in a formic acid solution relates chiefly to zinc ores containing from 2·5 to 4·0 per cent. of iron, and is not very readily directly applicable to iron ores. M. Bragard and G. Neumann have investigated this method, both authors apparently starting with neutral solutions, which, in the course of an analysis, are not always present, and the method of separation is necessarily then different. To neutralise the free inorganic acids the author employs a

* *Journal of the Society of Chemical Industry*, vol. xiv. pp. 427–428.
† *Stahl und Eisen*, vol. xvi. pp. 675–677.

solution of ammonium formate, made by neutralising formic acid of 1·15 specific gravity with ammonia of 0·96 specific gravity, the neutralisation not being carried beyond the acid reaction. The method the author uses in the case of iron ores is as follows:—5 grammes of the ore is brought into solution in a porcelain dish, from 20 to 25 cubic centimetres of dilute sulphuric acid being also added. The solution is then evaporated until sulphuric acid fumes appear, allowed to cool, extracted with water, filtered, the filtrate, now free from lead, diluted to from 300 to 400 cubic centimetres, and hydrogen sulphide passed through until the solution is completely saturated with it. Any copper sulphide that may have been formed is filtered off, and to the filtrate are added 25 cubic centimetres of the ammonium formate solution already mentioned, and 15 of formic acid. If the sulphuric acid was not greater than that above-mentioned, any zinc present is precipitated as zinc sulphide; but if much more sulphuric acid had been added, it must be first partially neutralised with ammonia before adding the formate. If much zinc is present, it is advisable to pass hydrogen sulphide into the warm solution for some time longer. If the zinc sulphide that was precipitated is a good white in colour it may be dissolved in dilute hydrochloric acid, and after driving off the excess of acid be precipitated by sodium carbonate, or it may be weighed directly as zinc sulphide. Small quantities of iron readily pass into the zinc precipitate, however, and if it is at all coloured it should be dissolved in hydrochloric acid, neutralised with ammonia until an alkaline reaction results, acidulated with formic acid, 15 cubic centimetres of this being added in excess, and then reprecipitated with hydrogen sulphide as before.

In a brown iron ore containing 33·4 per cent. of iron, 8·6 of manganese, and 0·28 per cent. of lead, 0·79, 0·81, and 0·80 per cent. of zinc was found in separate determinations. Other results are also given to show the applicability of the method. These are also of interest as showing the quantities of zinc which are often present, and are as follows:—

Percentage Composition.

Ore.	Iron.	Manganese.	Lead.	Zinc.
Brown iron ore	37·7	8·0	3·75	3·21
Brown iron ore	36·0	10·0	...	9·99
Greek manganese ore	29·8	21·2	0·98	2·19

The author observes that this method has been long in use in the laboratories of the Rhenish steel-works. The zinc sulphide is precipitated in a more flocculent form if the ammonium formate and formic acid are added to the zinc solution when saturated with hydrogen sulphide.

Determination of Phosphorus.—In the analysis of iron ore, the estimation of the phosphorus insoluble in hydrochloric acid is a source of some difficulty. C. T. Mixer * has experimented to find a way of obviating this, and finds that the best way is to filter off the insoluble residue, and after burning the paper, to calcine the residue in a platinum crucible at a red heat for a couple of minutes. It is then extracted with dilute hydrochloric or nitric acid at boiling temperature for three to five minutes, and filtered. The filtrate is then precipitated with molybdate in the ordinary way. Other methods are to treat the original sample with hydrofluoric acid, to calcine it below fusion point with sodium carbonate or magnesia, or simply to calcine the ore, but the calcination of the residue is to be preferred.

Analysis of Basic Slag.—O. Foerster † considers very fully the citrate method for the determination of the soluble phosphoric acid in basic slag and other materials, and the limitations connected with its use. The action even of one and the same solution, he points out, on any particular material, differs very greatly according to whether the material is hydrated or contains no water of hydration. It is wrong to generalise too freely. The author deals in this connection with various manurial sources of phosphoric acid, and then deals in detail with the citrate method as applied to basic slag. He states that the ammonium citrate solution, prepared in Wagner's way, takes up something of nearly every constituent of the slag; thus in one case there were dissolved in per cent.

P_2O_5	SiO_2	CaO	Fe_2O_3
15·96	8·29	41·76	9·22

or 75·23 per cent. of the slag under treatment. He is of opinion, however, that the Wagner solution may be not adequately acid. He deals at length with the chemistry of the subject, and observes that while an increase in the percentage of silica in a basic slag is found to correspond with an increased percentage of soluble phosphoric acid, it is not

* *Engineering and Mining Journal*, vol. lxii. p. 4.
† *Chemiker Zeitung*, vol. xx. pp. 391–396.

correct to consider that the solubility of the phosphoric acid is due solely to the silica.

In applying the citrate process to Wagner's method for the estimation of citrate soluble phosphoric acid in basic slags, F. Mach and Max Passon * avoid the troublesome molybdate separation in the following manner:—100 cubic centimetres of Wagner's solution is boiled in a half-litre flask with a very long narrow neck, with 10 cubic centimetres of sulphuric acid, 15 cubic centimetres of strong nitric acid, and a drop of mercury, until the liquid has become quite colourless. After cooling, 20 cubic centimetres of a 10 per cent. sodium chloride solution is added to precipitate the mercury, the mixture is diluted to 200 cubic centimetres, and 100 cubic centimetres of the filtrate is mixed with 100 cubic centimetres of the conventional ammonium citrate solution. After cooling, 25 cubic centimetres of magnesium mixture is added to precipitate the phosphoric acid.

O. Reitmer † has published an exhaustive examination of the citrate solubility question. Wagner's process being purely empirical, great care must be taken to prepare his ammonium citrate solution exactly according to his directions.

Gerlack's solution, containing citric acid only, gives in many cases the same results as Wagner's; its use is also more convenient, as it always gives a clear filtering solution.

Basic slags are now tested in Germany by simply estimating their citrate soluble phosphoric acid; but complaint is being made of serious analytical differences. M. Passon ‡ has found that, when carefully following the conventional (Wagner's) directions, the amount of phosphoric acid dissolved by the ammonium citrate solution is very constant. The analytical errors are, therefore, most likely caused during the further stages of the process. Excellent results are, however, obtained by the molybdate process if the temperature during the precipitation does not exceed 80°–85°; if higher, there is a danger of silicic acid precipitating.

The accuracy of Wagner's process is shown by the results of fifty analyses of basic slag, each done in triplicate, using slightly different methods.

* *Zeitschrift für angewandte Chemie*, 1896, p. 129.
† *Ibid.*, 1896, pp. 189–194.
‡ *Ibid.*, 1896, pp. 286–288.

III.—*THE ANALYSIS OF FUEL.*

The Determination of Ash.—R. Helmhacker * describes the method devised by Shtolba for shortening the time required for burning coal or graphite when determining the ash or the carbon. For this purpose finely divided precipitated silver is mixed with the sample, which is then heated in the presence of oxygen to a point below the melting-point of the silver.

Determination of Sulphur.—F. Nabery † describes a method for the determination of sulphur in illuminating gas and in coal. The current of gas is measured by a meter, and is burnt at a constriction in a combustion tube 45·5 centimetres long, having the constriction 30 centimetres from the forward end. A rapid current of air is drawn through the combustion tube. The products of combustion and the excess of air are drawn through a large U-tube, containing a centinormal solution of sodium hydroxide, in which the sulphuric acid is absorbed. Subsequent titration of this solution with centinormal sulphuric acid gives the amount of sulphur present in the gas. Since treatment of this solution with hydrogen peroxide in no way affected the result, the author is convinced that all the sulphur is completely oxidised to sulphuric acid by this method.

In Coal.—The coal is weighed in a platinum boat sufficiently large to contain all the ash, and placed in the forward portion of the combustion tube, air being drawn both from an inner hard glass tube, terminating at the constriction of the combustion tube, and in a slower current through a tube at the rear. A U-tube of considerable size is employed and a decinormal solution of sodium hydroxide used.

Determinations conducted on the ash of several varieties of coal treated in this manner gave a mean of only 0·043 per cent. of sulphur. The combustion is therefore practically complete.

* *Engineering and Mining Journal*, vol. lxii. p. 55.

† *Journal of the American Chemical Society*, vol. xviii. pp. 207–213.

STATISTICS.

CONTENTS.

I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the official report of Her Majesty's Inspector of Mines,* the production of coal in the United Kingdom in 1895 amounted to 189,661,362 tons. The production during the previous year was 188,277,525 tons. The total quantity of iron ore raised in 1895 was 12,615,414 tons, of which 7,231,835 tons was obtained from mines under the Coal Mines Regulation Act, 2,128,525 tons from mines under the Metalliferous Mines Act, and 3,265,054 tons from open works.

The production of pig iron in 1895 is officially stated to have been as follows:—

	Tons.
Hæmatite	3,266,210
Ordinary and basic	4,281,439
Spiegeleisen, ferro-manganese, &c.	155,810
Total	7,703,459

* "Mineral Statistics of the United Kingdom," London, 1896.

Iron Trade Statistics.—Returns which have been collected from the manufacturers by the British Iron Trade Association show that the quantity of pig iron made in the United Kingdom during the first half of 1896 amounted to 4,328,444 tons, which is at the rate of 8,656,888 tons a year. This is a record production. The greatest output hitherto recorded for a single year was that for 1882, when 8,586,680 tons was produced according to the returns of the Home Office, and 8,493,287 tons according to the returns of the British Iron Trade Association. In 1895 the output of pig iron in the United Kingdom was only 7,703,459 tons, so that the production for the first half of 1896 has been at the rate of 953,429 tons in excess of the output of 1895. The increase appears to be distributed over all the principal districts. In the Cleveland district alone the increase has been at the rate of 275,763 tons per annum. In Scotland, where the output of pig iron in 1895 was 1,048,774 tons, the make of the first six months in 1896 has been estimated at the rate of 1,240,000 tons a year, or about 192,000 tons in excess of the output of 1895. In the other districts the advance has been less marked, but it has been sufficiently notable in most of them to call for attention.

The production of steel during the first half of 1896 was as follows: *—

	Tons.
Bessemer steel ingots, acid	688,163
,, ,, basic	217,359
,, ,, total	905,522
Bessemer steel rails	449,924
Open-hearth steel ingots, acid	966,014
,, ,, basic	97,784
,, ,, total	1,063,798

Blast Furnace Statistics.—The following is a summary of the position of furnaces built and in blast on June 30, 1896: †—

Total number of furnaces built on June 30, 1896	690
Total number of furnaces in blast on June 30, 1896	375
Decrease in the number of furnaces built since March 31, 1896	5
Increase in the number of furnaces in blast since March 31, 1896	2
Furnaces blown in since March 31, 1896	7

Derbyshire (1): Renishaw Iron Co., 1. *Lincolnshire* (1): North Lincolnshire Iron Co., Ltd., 1. *Yorkshire, W. R.* (1): Brown, J. & Co., Ltd., 1. *Durham* (1): Carlton Iron Co., Ltd., 1. *Monmouthshire* (3): Blaenavon Co., Ltd., 1; Ebbw Vale Steel, Iron and Coal Co., 1; Pyle and Blaina Works, Ltd., 1.

* *Iron and Coal Trades Review*, vol. liii. p. 465.
† *Ryland's Iron Trade Circular, Supplement*, 1896, p. 21.

Furnaces blown out since March 31, 1896 5
Cumberland (2): Kirk Bros. & Co., 1; Lonsdale Hæmatite Iron and Steel Co., 1. *Lancashire* (1): Millom & Askam Hæmatite Iron Co., Ltd., 1. *Leicestershire* (1): Holwell Iron Co., Ltd., 1. *Yorkshire* (1): Gjers, Mills & Co., 1.

Furnaces being built at present time 2
Staffordshire, South (1): Roberts & Co., 1. *Glamorganshire* (1): Swansea Hæmatite Iron Co., 1.

Furnaces being re-built at present time 2
Staffordshire, South (1): N. Hingley & Sons, 1. *Glamorganshire* (1): Briton Ferry Works, Ltd., 1.

The West of Scotland Industries.—A comprehensive report has been published of the iron ore and coal output, and the pig iron, malleable iron, and steel manufactures of the West of Scotland, with other information of a general character.*

II.—*AUSTRALASIA.*

Mineral Statistics of New South Wales.—From the annual report of the Department of Mines and Agriculture of New South Wales for 1895,† it appears that the output of coal was 3,738,589 tons. The quantity of coke manufactured in 1895 is stated to have been 27,630 tons. The production of iron for the same period is given as 2403 tons.

Coal Production in Victoria.—The annual report of the Secretary of Mines, Victoria, states that the output of coal during 1895 was 194,226 tons. An increase is shown of 22,566 tons compared with the quantity raised in 1894. The mines from which the bulk of the above total quantity was obtained were the Coal Creek Proprietary, 102,065 tons; Jumbunna, 40,178 tons; Korumburra, 29,755 tons. In addition to the bituminous coal mentioned above, 1606 tons of brown coal were raised at Moe, and valued at £1004; and also 350 tons of lignite were worked at Lal Lal, estimated to be worth £43. The total quantity of coal raised in the Colony up to the end of 1895 was 558,889 tons.

Mineral Statistics of New Zealand.—According to the official returns ‡ the quantity of coal mined in New Zealand in 1895 amounted

* *Iron and Coal Trades Review*, vol. lii. pp. 173-184.
† Report for 1895, p. 74, Sydney, 1896.
‡ Papers and Reports relating to Minerals and Mining, 1895, pp. 1, 22.

to 740,827 tons, which shows an increase on the previous year of 21,281 tons. The quantity imported from the Australian colonies was 102,150 tons, and the quantity exported was 92,744 tons.

The output of the different classes of coal was as follows:—

	Tons.
Bituminous coal	429,981
Pitch coal	104,566
Brown coal	180,870
Lignite	25,410

The number of men employed was 1799, the average output per man being 411 tons.

III.—*AUSTRIA-HUNGARY.*

The Iron Industry of Carinthia.—The maximum output * of iron ore in Carinthia during the period 1888–92 was in 1890, when it reached 100,083 tons. In 1887 there were eighteen blast-furnaces in blast. Other statistics are given, but they nearly all relate to years preceding 1890.

Mineral Statistics of Hungary.—In the year 1895,† 58·6 per cent. of the total area of all the mining concessions related to coal-mining, and 17·1 per cent. to the mining of iron ore. The total number of workpeople in the years 1894 and 1895, and the wages they earned per day, were as follows:—

	1894. Number.	1895. Number.	1894. Wages.	1895. Wages.
			Florins.	Florins.
Men	52,674	54,859	0·30 to 1·90	0·40 to 2·50
Women	4,770	2,491	0·20 ,, 0·60	0·30 ,, 0·60
Boys	5,139	4,981	0·14 ,, 0·60	0·12 ,, 0·70

For every 1000 workpeople 1·2 were killed by accident, and 2·4 severely and 7·7 slightly injured. Of 405 accidents, 110 were due to falls of rock, 18 to blasting, 20 to falls, 82 to winding, 49 to fire-damp explosions, and 96 to various other causes. Altogether there

* *Oest.-ung. Montan- und Metallindustrie-Zeitung*, 1896, No. 17; *Stahl und Eisen*, vol. xvi. p. 602.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 516–520.

were 74 fatal accidents in 1895, as compared with only 5 in 1894. The total number of accidents, however, had diminished on the year from 709 to 701. The production during the year included :—

	1895.	1894.
	Metric Tons.	Metric Tons.
Coal	1,068,046	1,037,323
Brown coal	3,517,901	3,181,072
Briquettes	29,422	30,057
Coke	12,033	10,250
Forge pig iron	322,206	312.148
Foundry pig iron	21,459	17,837
Calcined iron ore exported . .	350,575	237,476

The total production of the mine and metallurgical works of Hungary in 1895 was of the value of £3,311,997, as compared with £3,066,650 in 1894. The value of the pig iron made was just one-third of that of the total production, and it increased, consequently, by 2 per cent. on the year. Details are given as to the chief producers both of coal and pig iron.

A description has been published of the interesting mining and metallurgical exhibits at the Hungarian National Exhibition.*

Mineral Statistics of Bosnia and Herzegovina.—In 1895 there were employed in Bosnia and Herzegovina 1278 workpeople at nineteen mining undertakings.† Of these, 871 were employed in coal-mining. At metallurgical works 835 workpeople were employed, 310 of these being engaged at the Vares ironworks, and 227 at the Zenica steel-works.

At the Vares ironworks a second blast-furnace was built and blown-in during the year, while a new blowing engine and battery of boilers for this furnace was also put into work. A new open-hearth plant was erected at the Zenica works, and this will shortly be put into operation. The production during the year was as follows :—

	Metric Tons.
Brown coal	198,532
Iron ore	12,739
Manganese ore	8,145
Chrome ore	707
Pig iron	3,771

* *Colliery Guardian*, vol. lxxii. p. 30.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p 303.

The Austrian Alpine Mining Company.—The mines and works of this company produced in 1895:*—

	Metric Tons.
Brown coal	805,403
Iron ore, raw	789,053
Iron ore, calcined	582,993
Pig iron, white and mottled	169,875
Pig iron, grey	70,028
Castings	11,217
Bessemer ingots	43,132
Open-hearth ingots	63,251

A large quantity of iron and steel manufactures and semi-manufactures was also made. The most important blast-furnace plants belonging to the company were those at Donawitz, Hieflau, and Schwechat, with out-turns amounting respectively in 1895 to 57,269, 43,415, and 55,754 tons. Of twenty-seven blast-furnaces belonging to the company sixteen were in blast. Of slag-bricks 3,155,496 were made; six Bessemer converters and twelve open-hearth furnaces were also in operation. The building of a new open-hearth at Donawitz was commenced. This is to take a 20-ton charge, and this works will then possess seven open-hearths. The company gave employment during the year to 4284 workpeople in their collieries, 1912 in their iron ore mines, 8687 in their ironworks and shops, and 326 in forestry and peat-cutting. 26½ per cent. of the total pig iron made was made with charcoal.

Accidents in Austrian Mines.—The total number of fatal accidents in Austrian collieries in 1894 was 276, while 226 men were severely injured.† In the brown coal mines these numbers were respectively 93 and 314, and in the iron ore mines 3 and 33. There was raised respectively for each fatal accident 34,686 tons of coal, 186,371 of brown coal, and 404,912 of iron ore. For each accident of whatever kind, whether fatal or otherwise, these numbers were respectively 19,069, 42,586, and 36,810 tons. Details are given as to the causes of these accidents. Had it not been for the terrible explosion at the Larisch-Mönnich Colliery, in the Karwin district, by which 234 men lost their lives, the death-roll of the Austrian collieries would have been a comparatively small one, and not so greatly above the average. The total number of men employed was 53,751 at the collieries, 44,239 at the brown coal mines, and 4331 at the iron ore mines.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 285–287.
† *Ibid.*, vol. xliv. p. 219.

Production of Brown Coal in Bohemia.—The production of brown coal in Bohemia in 1895 was as follows: *—

District.	Production.	Workpeople Employed.
	Metric Tons.	
Elbogen-Falkenau	1,881,941	4,947
Teplitz-Brüx-Komotau . . .	12,840,210	21,778
Totals . . .	14,722,151	26,725

This output shows an increase of 739,125 tons as compared with the output of the previous year. The value varied from 1·36 florin to 1·88 florin per ton in the different districts. The chief producing company was the Brüx Coal-mining Company, with an output exceeding 3,000,000 tons. The transportation of brown coal over the different railway systems represents 12,540,305 tons, an increase of 545,752 tons on the year. At present 52·5 per cent. of the total output serves for internal consumption, and 47·5 per cent. is exported. The home consumption is rapidly increasing.

IV.—*BELGIUM.*

Mineral Statistics.—During the first six months of 1896 † the 119 collieries in activity produced 10,386,500 tons, against 10,091,112 tons during the corresponding period of 1895, and the Belgian blast-furnaces turned out 228,039 tons of steel-making pig iron, 162,197 tons of forge pig iron, 40,745 tons of foundry pig iron, making, for the half year, a total quantity of pig iron of 430,981 tons. The finished iron works produced 64,677 tons of rails and plates and 192,661 tons of other products; and the steel-works 279,841 tons of ingots and castings, together with 230,908 tons of forged steel products, including rails and plates.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 437.
† *Moniteur des Intérêts Matériels*, vol. xlvi. p. 1997.

V.—*CANADA.*

Mineral Statistics.—B. T. A. Bell * has published a careful digest of information relating to the history, organisation, and operations of all Canadian mining, smelting, and iron and steel companies.

The mineral industry in the Dominion has made distinct progress, the value of the coal produced in 1895 being 7,774,178 dollars; of iron, 238,070 dollars; and of coke, 143,047 dollars. There is first a classified index to companies, and then separate sections on asbestos, gas and oil, coal-mining, and trade, gold, silver, and lead, copper, iron, and steel, &c.

The coal areas of the Dominion cover 97,200 square miles. In Nova Scotia the coal area covers 635 square miles, and the coal there is of the soft bituminous variety. All coal in Nova Scotia belongs to the Government, which received in royalties in the year ended 30th September 1895, 21,464,776 dollars. In Manitoba and North-West Territory it is estimated that there is coal sufficient for an output of 2000 tons a day for over a hundred years. The total output of coal in British Columbia for the year ended 31st December 1895 was 939,634 tons, of which 736,333 tons were exported. The exports of Canadian coal in 1894 were 995,998 tons, of the value of 3,321,565 dols., or about 3½ dollars per ton. At the New Vancouver Coal-mining and Land Company they use naked lights, and they have a Guibal fan, 36 feet in diameter and 12 feet wide, giving 119,000 feet of air per minute. They also use electricity for haulage, having three 30-ton electric motors made by the Edison General Electric Company.

The consumption of pig iron, both imported and domestic, in Canada was, in 1889–90, 111,986 tons, while in 1893–94 it was 107,804 tons. Ten years ago Canada imported the bulk of its supplies from Great Britain, but now the ocean liners can scarcely get a load.

Some notes on the iron industry in Canada are given by G. E. Drummond.† The Nova Scotia Steel Company has made 19,410 tons, the Londonderry Iron Company 17,440 tons, and the Canada Iron Furnace Company 6598 tons. Iron was also made at Drummondville, at the Picton Charcoal Iron Company, and the Hamilton Furnace is to go into blast. The question of bounties is discussed.

There are now eight blast-furnaces and fifteen rolling-mills and steel-

* *The Canadian Mining, Iron, and Steel Manual*, Ottawa, 1896.

† *Journal of the Canadian Mining Institute*, vol. i. pp. 145–158.

works in Canada; considerable progress having been made in recent years.*

Coal in British Columbia.—The twenty-second Annual Report of the Minister of Mines for the year ending 31st December 1895 contains very full and clear information on the subject of the coal industry, and is accompanied by a table showing the output of each year from 1874 to 1895 inclusive.† From it is seen that the output for 1895 was 939,654 tons, against 1,012,953 tons in 1894, this falling off being due to the very low prices which have ruled, being the lowest known in the trade. This low price also accounts partly for the increase in the home consumption, which amounted to 188,349 tons, as against 165,766 tons in 1894. A new outlet for the coal is being found in coking, and the capacity now or shortly in operation will be 140 tons of coke a day. The description of the various collieries, with their equipment and plant, is interesting and exact in detail.

VI.—*CHINA.*

Iron Trade Statistics.—The imports of iron and steel into the port of Shanghai were as follows in the years mentioned: ‡—

	1894.	1893.
	Metric Tons.	Metric Tons.
Nail iron	16,745	14,085
Bar iron	5,017	3,325
Pig iron	4,776	3,627
Other kinds and scraps	19,989	17,139

Of sewing needles, 2,126,700 thousands were imported in 1894, as compared with 2,542,000 thousands in the previous year.

Other statistics § show that, despite the war with Japan, Chinese imports of iron and steel again showed an increase in quantity in

* *Swank's Directory to the Iron and Steel Works of the United States*, 13th edition.

† Annual Report of the Minister of Mines for the year ending December 31, 1895, being an account of mining operations for Gold, Coal, &c., in the Province of British Columbia, Victoria, B.C., p. 87, with seven maps.

‡ *Deutsches Handelsarchiv*, 1896, p. 81; *Stahl und Eisen*, vol. xvi. p. 652.

§ *Stahl und Eisen*, vol. xv. p. 1117.

1894, as is seen from the following table, showing the imports into China for the years 1893 and 1894 to have included :—

	1894.	1893.
	Piculs.	Piculs.
Iron nails	345,000	296,927
Bar iron	125,000	107,727
Hoops	24,074	15,397
Sheet and plate . . .	56,949	38,347
Wire	84,374	61.498
Pig iron	90,208	62,088
Old iron	509,656	501,431
Steel	59,100	122,115

In addition to the above, 486,295 tons of coal was imported into China in 1894, and 428,940 tons in 1893. Of needles, 2,422,000,000 were imported in 1894, and 2,592,000,000 in the previous year. The value of the machinery imported in 1893 was 931,000 Haikwan taels, and in 1894, 1,120,000 Haikwan taels. Owing to changes in the exchange, one Haikwan tael was worth about 4s. in 1893, and 3s. 3d. in 1894. Calculated on this basis, the value of the machinery was nearly alike in the two years, £186,000 and £182,000 respectively. The total value of coal and metal imported is given as 10,607,000 taels in 1893, and 12,206,000 taels in 1894—say, £2,121,400 and £1,983,500.

VII.—*FRANCE.*

The Iron Trade.—In 1895 the blast-furnaces of France produced over 1½ million tons of forge pig iron, and nearly half a million tons of foundry iron.* The main centre of the iron industry of France is in the department of the Meurthe and Moselle, and it owes its existence there to the neighbouring ore basins of Longwy and Nancy. While the total production of France increased by 16 per cent. in the years 1880–1894, that of the Meurthe and Moselle increased by as much as 138 per cent., its output having risen from 538,132 tons in 1880 to 1,284,572 in 1894.†

* See *Journal of the Iron and Steel Institute*, 1896, No. I. p. 553.

† *Stahl und Eisen*, vol. xvi. p. 384; *Annales des Mines*, vol. ix.; *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xl. pp. 98–101.

In the Longwy district thirteen works possess thirty-eight blast-furnaces, of which, in 1895, thirty-three were in blast. The total monthly production of pig iron is placed at 70,700 tons. In the Nancy district seven works possessed, in 1895, twenty-four blast-furnaces, of which sixteen were in blast. The monthly out-turn of pig iron was about 30,000 tons. The majority of the works in the Longwy district have combined since 1887 to sell their pig iron jointly, and three of the Nancy works have also done this. Seven basic steel plants exist in the Meurthe and Moselle district, the increase in the last year or two being due to the lapse of the basic patents. It is stated that the basic plants above referred to have also entered into a mutual arrangement for the sale of their products. The basis of the blast-furnace agreement is the price of coke. It is thought likely that owing to the enormous ore deposits of the Longwy basin, iron manufacture there will make further progress.

Iron Trade Statistics.—The production of iron and steel in France * during the first half of 1896 was as follows:—

	Metric Tons.
Forge pig iron	893,909
Foundry pig iron	252,685
Total pig iron	1,146,594
Iron rails	417
Merchant iron	347,885
Plates	43,364
Total wrought iron	391,666
Steel rails	88,389
Merchant steel	218,042
Steel plates	106,105
Total steel	412,536
Bessemer ingots	338,436
Open-hearth ingots	199,811

VIII.—*GERMANY.*

Preliminary Iron Trade Statistics.—Dr. Rentzsch † has collated the following statistics for the Verein deutscher Eisen und Stahl Industrieller, showing the production of the mines and

* *Comité des Forges de France Bulletin*, No. 1104.
† *Stahl und Eisen*, vol. xvi. pp. 395–396.

works in the German Empire, including Luxemburg, in the year 1895:—

Material.	Quantity, Tons.		Value, £.	
	1895.	1894.	1895.	1894.
Coal	79,163,615	76,741,127	26,946,178	25,455,010
Brown coal . . .	24,713,198	22,064,575	2,912,331	2,657,582
Iron ores	12,349,595	12,392,065	2,053,787	2,108,877
Pig iron and direct castings	5,431,007	5,345,632	11,730,536	11,458,166
Castings	1,093,586	1,054,362	8,836,851	8,363,622
Weld iron and steel . .	1,051,171	1,105,477	5,716,758	6,265,180
Ingot iron and steel . .	3,933,395	3,618,252	20,474,095	19,193,262

The consumption of pig iron in Germany, including Luxemburg, amounted in 1895 to 0·0704 ton per head of the population, the total out-turn being at the rate of 0·1051 ton. In 1894 these figures were respectively 0·0730 and 0·1055, while in 1880 they were 0·0393 and 0·0612.

German Ironworks in 1895.—The Donnersmarck works belong to the Upper Silesian Iron and Coal Company.* In 1895 two blast-furnaces were in blast during the whole year. These made 45,425 tons of pig iron—an average of 62·23 tons a day per furnace. The iron foundry and machine shops produced 7898 tons of finished products. The ore raised from the mines belonging to the company amounted to 13,798 tons, brown hæmatite being the ore mined. The Concordia colliery raised 629,600 tons of coal. Of coke, 76,525 tons of lumps, 2662 of nuts, 13,216 of smalls, and 7508 of cinder coke was made. In the production of this coke there were obtained as by-products 5309 tons of tar and 1575 of ammonium sulphate.

The works of the Rhenish Mining and Smelting Company produced 72,915 tons of pig iron, as compared with 83,341 tons in 1894. There was smelted 137,297 tons of iron ore, 95,950 tons of coke, and 26,241 of limestone. The foundry made 7580 tons of castings.

German Blast-Furnace Progress.—F. W. Lürmann † describes the progress made in the last hundred years by the German blast-furnace industry. It was on 21st September 1796 that, at Gleiwitz, the first practical experiment was made with a furnace built to use

* *Stahl und Eisen*, vol. xvi. pp. 429–431.

† Paper read at the meeting of the Verein Deutscher Eisenhüttenleute, September 20, 1896.

coke only as fuel. The first experiments made in this direction in Germany were carried out at Sulzbach, in the Saar district, in 1765; but up to the date first mentioned, 1796, all such trials were made with furnaces built to work with charcoal. The author refers to the fostering policy of Frederick the Great in connection with mining and metallurgy as well as other industries, and passes historically in review the progress of the iron trade. He gives a sectional elevation of the Gleiwitz coke-furnace, which was indeed the first coke-furnace ever built on the Continent of Europe, and in addition a number of others, showing the gradual transition of form between this furnace and one of modern construction. The blowing-engines, stoves, and other appliances are also considered. The earliest furnace—that of 1796—had a cubic capacity of 49·83 cubic metres, with a ratio of height to diameter at the boshes of $3\frac{3}{4}:1$; in 1850 this ratio was, in the case of a furnace quoted, 3·2 : 1, the furnace having a capacity of 112·69 cubic metres; in 1867 this ratio, in the case of a furnace built in that year, was 3·3 : 1, the furnace capacity amounting to 219·1 cubic metres; while in the case of the most modern furnace illustrated, built in 1888, the ratio was 3·6 : 1, and the cubic capacity of the furnace was 434·03 cubic metres.

The author gives a number of statistics relating to the iron trade, and he shows that in 1796 the total make of pig iron in Prussia was only 15,124·5 metric tons. In 1883 and 1895 the proportions of the total make of pig iron in Germany were as follows for the different kinds of pig iron produced:—

Year.	Total Make of Pig Iron.	Per Cent. of Total.			
		Forge and Spiegeleisen.	Acid Bessemer.	Basic.	Foundry.
	Metric Tons.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1883	3,380,788	64·1	14·7	10·9	10·3
1887	3,907,364	48·8	11·1	27·5	12·6
1891	4,452,019	39·2	8·7	38·3	13·8
1895	5,788,798	26·3	7·7	50·1	15·9

This table shows the rapid decadence of the puddling process, and the equally rapid rise of the basic process.

The utilisation of the slag has made satisfactory progress in recent years. The granulated slag is utilised in large quantities in the manufacture of mortar. There are also seven presses in use for the manufacture of slag bricks for building purposes, each of these presses being

capable of producing 8000 bricks a day. Altogether, however, fifty-nine such presses have been manufactured. In other ways, too, progress has been made in the direction of the profitable utilisation of the slag for a variety of purposes.

The transition from pipe to brick stoves is also considered, and the advantages of the brick stoves are generally stated. The Cowper stoves are those which have been most generally adopted in Germany. Five or more are now built for each furnace instead of the two that were formerly considered adequate. Formerly Cowper stoves were built some 16 metres in height and 6 in diameter, but now they are built 33 in height and 7½ in diameter. Formerly, too, the heating surface of the bricks was but 5000 square metres, whereas now 35,000 is considered necessary. How important is this question of stoves is shown, the author observes, by the fact that no less than seventy-eight articles on the subject have appeared since 1882 in the one journal, *Stahl und Eisen*.

The author refers generally to the mechanical appliances and labour-saving devices that have been introduced into ironworks practice, including the employment of electricity. The further direct utilisation of blast-furnace gases is also considered, and he draws attention to a statement that gas-engines up to 1200 horse-power are suggested for the direct combustion of blast-furnace gas at the Hörde works for the purpose of driving dynamos, and thus transmitting the power to the rolling-mills. The author mentions a large number of other ways in which improvement has been made in blast-furnace progress during the period he considers; but he points out that it is impossible to discuss the whole of these within the limits of a single paper, and he concludes by observing that if the blast-furnace output of Germany goes on increasing as it has of late years, it will soon equal that of the United Kingdom.

Mineral Statistics of Prussia.—According to the official statistics,* there was produced in Prussia in the year 1895:—

	Metric Tons.
Coal	72,621,509
Brown coal	20,114,877
Asphalt	14,391
Petroleum	1,612
Iron ore	3,726,724
Nickel ore	2,058
Manganese ore	39,882

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliv. pp. 22–28.

The metallurgical production included :—

	Metric Tons.
Charcoal pig iron	13,161
Coke pig iron	3,765,613
Total production	3,778,774

Mineral Statistics of Saxony.—According to the official statistics,* the production of coal in the kingdom of Saxony in the year 1895 amounted to 4,435,328 metric tons, and that of brown coal to 1,018,486; the output per miner being 218·1 tons in the collieries, and 480·8 tons in the brown coal mines: the production of iron ore amounted to 7331 tons. No pig iron was made in Saxony in 1895.

Mineral Statistics of Bavaria.—In the year 1895 † the production of the mines and smelting works of Bavaria included the following:—

	Total Mines or Works.	Active Mines or Works.	Work-people Employed.	Production, Metric Tons.
Coal	28	5	7,760	496,894
Brown coal	19	4	524	6,423
Iron ores	70	5	105	3,129
Manganese ore . .	3	. .	4	150
Pig iron and castings .	87	85	15,192	139,539
Bar iron	16	15	9,713	48,596
Wire and sheets . .	1	1	...	251
Steel	4	4	2,098	96,829

Details are also given showing the production of other minerals. Of graphite, 3751 tons was produced at 37 active mines, and 106,925 tons of fireclay was obtained from 103 workings. The total quantity of iron and steel of all kinds that was produced amounted to 285,215 tons, and its value amounted to £1,495,017.

The Iron Ore Mines of the Siegen District.—In the Siegen iron ore district of Germany the quantity of iron ore raised amounted to 1,664,359 tons in 1895, as compared with 1,732,176 tons in the previous year.‡ This diminution is due to a diminished blast-furnace out-turn, and not to any falling off in the yield of the mines, the quantity of pig

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1896, p. 74.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 361-362.
‡ *Stahl und Eisen*, vol. xvi. p. 333.

iron made in 1895 having amounted to but 306,423 tons, or 39,194 tons less than the out-turn in the previous year. The output of iron ore, it will be seen, showed a diminution of 67,817 tons, so that the two reductions practically correspond. While the out-turn of pig iron diminished, that of the rolling-mills showed an increase of 12,761 tons, that of the foundries one of 3297 tons, and the works making galvanised iron had an out-turn 1905 tons greater in 1895 than it was in 1894.

Westphalian Collieries.—Details as to the cost of production of the ton of coal are given in connection with nine collieries in the Westphalian coalfield. The actual first cost of the ton of coal is shown to vary in these from 4s. 1d. to 6s. 3d.*

Iron Trade Statistics of Luxemburg.—According to the official statistics,† the quantity of iron ore produced in the Grand Duchy of Luxemburg in 1895 was 3,913,076 tons, 4587 workmen being employed.

There were 23 blast-furnaces, employing 2080 workmen daily.

There were 8 foundries, employing 290 workmen, and producing 8747 tons of cast iron. The production of pig iron in 1895 was 694,814 tons.

IX.—*INDIA.*

The Production of Coal and Iron Ore.—From Dr. Watt's ‡ review of the mineral production of India for the past year, it appears that the production of coal, though increasing with great rapidity, is not keeping pace with the consumption. In 1895 the production was 4,370,000 tons, or just 55 per cent. more than the previous year (ten years ago the production was just 1¼ million tons), but the imports of coal were 800,000 tons, the largest on record except one year. Coal is not used for domestic purposes in India, and this growing production and importation shows growing industry. Fifteen years ago the total supply of coal, local and foreign, in India was 1½ million tons; last year it was over 5 millions. The iron industry, on the other hand, progresses very slowly, the product last year being only 46,000 tons. The furnaces are almost wholly confined to Bengal, and to those places

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 364.
† *Moniteur des Intérêts Matériels*, vol. xlvi. p. 2669.
‡ *Colliery Guardian*, vol. lxxii. p. 772.

where coal is abundant in the immediate neighbourhood of the ore, and where smelting can be carried on by European methods. In the Central Provinces ore exists in abundance, but the smelting is primitive, and there are no authentic statistics. In Madras there is abundance of ore, but no fuel, while in Bombay there are both ore and fuel, but enterprise has not yet been systematically directed to smelting.

J. Grundy,* Inspector of Mines, in his report gives a large amount of interesting information regarding colliery mining, with a description of the four principal collieries, the Warora, the Mohpani, the Umaria, and the Singareni.

An article has been published describing the coal industry in India.†

X.—*JAPAN.*

Coal Production.—According to the *Tokyo Economist*,‡ the production of coal in Japan amounts to about 3,000,000 tons a year, of which one-half is consumed at home, and the remainder is shipped abroad, chiefly to Hong-Kong, Shanghai, Chefoo, Newchwang, Singapore, and San Francisco. The exported coal is obtained from Miike and other collieries in Kyushiu, and also from the collieries of Hokkaido. In Hong-Kong, where about 600,000 tons of Japanese coal were imported last year, it is used by steamers and factories. The possible rivals of Japanese coal in Hong-Kong are the collieries of Tonquin and Australia, but they need not be regarded with any dread. Cardiff coal, so long as the silver price of gold does not appreciate, cannot be exported to the East for ordinary use. In Shanghai, Newchwang, and Singapore, Japanese coal is used for steamships, factories, and the kitchen. In San Francisco it is used for generating gas. The price of the article is a great obstacle to extending its sale in San Francisco, and at present a reduction is out of the question, as ships that would carry coal to San Francisco find it difficult to get a return cargo. Coal-mining has made remarkable progress during the last two decades, for whereas the output amounted to only a little over 560,000 tons in 1875, the supply was over 3,307,000 in 1893. The figures for 1894 are not yet obtainable, but those engaged in the business estimate the output at 10 to 20 per cent. higher.

* *Colliery Guardian*, vol. lxxii. pp. 408–409.
† *Indian and Eastern Engineer*, vol. xxvi. p. 187.
‡ *The Mining Journal*, vol. lxvi. p. 1375.

German Exports to Japan.—In connection with the question of the recent trade treaty made between Germany and Japan, *Stahl und Eisen* * publishes some statistics relating to the iron trade exports from Germany to Japan. These included :—

—	1892 and 1893.	1894 and 1895.
	Metric Tons.	Metric Tons.
Rails, ties, and fastenings	1,360	5,434
Bar, angle, and shaped iron	21,546	37,172
Plates and sheets	635	1,528
Wire	7,364	8,353
Wire nails	23,968	25,891
Iron bridge parts	304	1,819
Cast iron machine parts	538	911
Other iron and iron wares	832	1,198
Locomotives	141	186
Railway waggons	196	206

With regard to wire nails, it is pointed out that, next to England, Japan is Germany's largest customer, and the exports of this product to Japan are increasing year by year.

The imports into Germany from Japan amount annually to about £350,000 or £400,000, the chief article being copper, of which Japan furnished Germany in 1895 with 1932 tons, valued at nearly £100,000.

XI.—*MEXICO.*

The Iron Trade.—It is stated † that there exists in Mexico at the present time 14 blast-furnaces and 6 rolling-mills and steelworks.

XII.—*RUSSIA.*

Coal and Iron in Russia.—A. F. Stahl ‡ observes that the steadily increasing output of the Donetz coalfield led in 1895 to an excess of supply over demand. The ironworks are making equally rapid progress, and a new works with six blast-furnaces is shortly to be built at Pawlograd, and other works are also foreshadowed. The ores

* Vol. xvi. pp. 355–357.

† Swank's *Directory to the Iron and Steel Works of the United States*, 13th edition; *Stahl und Eisen*, vol. xvi. p. 317.

‡ *Chemiker Zeitung*, vol. xx. pp. 404–405.

treated are largely derived from the neighbourhood of Krivoi Rog, on the borders of the governments of Ekaterinoslav and Kherson, that at the village of Alexandrov Dar being the most southern mine. Miocene limestone is the chief country rock. A fine white quartz sand is in places found interstratified with this, and below comes weathered gneissose, chloritic and talcose slates, with, in places, greenstone. The ore found at Alexandrov Dar is mostly itaberite, with from 40 to 50 per cent. of iron, though in parts this becomes slightly magnetic, and then contains from 65 to 70 per cent. of the metal. The iron ore deposit of the greatest interest is near the Saksagan, where slates like those above mentioned form the footwall of an amorphous and slightly magnetic iron ore containing about 70 per cent. of iron, and reaching to more than 30 yards in thickness. To the north-east of Krivoi Rog are quite a large number of iron ore mines, with large ore deposits. The Krivoi Rog iron ore field has, as developed, a length of from 25 to 30 miles; but the author considers it very much more extensive, and he thinks its length should be placed at at least over 60 miles, with a breadth of from 30 to 37.

The clay and spathic ores of the Donetz basin are widely extended, but they are not rich enough in iron to be able to compete with the other existing ores. Later on they will become valuable. Railway communication is improving, and in January 1897 a new railway 125 miles in length is to be opened, extending to the town of Berdiansk, on the Sea of Azov. This has other connections, and will open up rich magnetite ores.

The Railways of the Russian Empire.—The following table * gives the length in miles of Russian railways in April 1896:—

In 1880 the total length was 14,134 miles, and in 1894, 20,800 miles.

	Open to Traffic.	In Course of Construction and Sanctioned.
	Miles.	Miles.
Russia in Europe—		
State railways	13,559	1,498
Private railways	8,978	2,235
Russia in Asia—		
Siberian	1,221	2,109
Cis-Caspian	895	519
Finland	1,495	75
Totals	26,148	6,436

* *Vestnik Finansoff*, No. 27, 1896. Abstracted by Mr. G. Kamensky, Assoc. R.S.M.

The Iron Trade at Nishnij-Novgorod Exhibition.—J. Kowarsky * describes the iron trade exhibits shown at the Nishnij-Novgorod Exhibition in Russia. Dealing first with the Ural, he observes that of the 110 metallurgical works existing there, 100 are represented at the exhibition, and nearly every exhibit includes not only the manufactured articles, but also the raw materials. In connection with almost every one of the Ural ironworks are vast tracts of wooded land. Fir is the most common wood, but birch and other wood suitable for metallurgical purposes also occurs. The Northern Ural belongs to the Jurassic period. Here the ore is mostly a very pure form of spathic carbonate, but the Southern Ural is rich in other ores. Thus the ore mined by the Sigasin works is a brown hæmatite, containing from 50 to 60 per cent. of iron, with no sulphur at all, and but 0·06 of phosphorus. The Stroganoff ores contain from 45 to 55 per cent. of iron in the case of the brown hæmatites, and up to 65 per cent. in the magnetites. Although the ore deposits are very numerous, it is those near the rivers that are chiefly worked, and either by open working or deep mining, though it is rarely that these exceed in depth some 50 to 70 yards. In the last few years the annual output of the 550 more important mines has amounted to about a million tons of ore. The mines are often at long distances from the works, and to save transport the ore in consequence is calcined at these mines before shipment, a diminution of 25 per cent. in the weight being the result. For the calcination of 10 tons of ore, about 6 cubic metres of wood are required. More rarely, charcoal is used for this purpose. Notwithstanding this, and despite many primitive conditions, 50 per cent. of the total pig iron output of Russia is derived from the Ural district; but even this is a very small fraction of the possible production of this region as soon as the railway means of transport became more complete. The pig iron made is utilised at the ironworks where it is produced. For a works to purchase such iron is an extremely rare occurrence. The excess of that produced over that worked up in the district is exported as far as to St. Petersburg, and large quantities of it are used in the Moscow region. The shape of the blast-furnaces of the Ural varies with their age. Some of the works are very old, and go back as far even as the end of the seventeenth century. The older furnaces are mainly charcoal furnaces, from 15 to 21 metres in height, and with from 6 to 8 tuyeres. The consumption of charcoal for the unit quantity of pig iron made is usually from 1·6 to 1·8, according to the

* *Stahl und Eisen*, vol. xvi. pp. 781–784, 825–827.

kind of charcoal used. Hot blast is generally employed, and the waste gases from the blast-furnaces are utilised in heating the blast and in driving the blowing engines, but of the 110 blast-furnaces in the Urals, 40 still work with cold blast. The fluxes used are very pure. Thus the limestones used contain only 4 per cent. of silica and sand. In neutral working about 10 to 15 per cent. of lime is added. The slags are acid and glassy in character. The following are analyses of the pig iron made at the Cholunitz works:—

Description.	Cold Blast Pig Iron.			Hot Blast Pig Iron.	
	White.	Mottled.	Grey.	Mottled.	Grey.
Graphite	0·4	2·9	3·5	1·7	2·7
Combined carbon	2·9	0·9	0·3	1·5	0·6
Silicon	0·3	0·2	0·8	0·4	1·8
Manganese	0·3	0·9	0·3	0·2	0·7
Phosphorus	0·15	0·13	0·15	0·14	0·13
Sulphur	0·07	0·06	0·03	0·04	0·03

The low manganese contents is a characteristic of the Ural pig iron. Of the 600,000 tons of pig iron which forms the total out-turn of the Ural blast-furnaces, 90 per cent. is produced by private works, and 10 per cent. from those belonging to the State. There are in use in all 100 blast-furnaces, 90 blowing engines, and 85 calciners. The author then deals with the uses made of the metal, and, referring to the Perm Ordnance Foundry, observes that the Slavianoff electric welding process is in use there. Two dynamo machines, each yielding a current of 100 volts and 100 ampères, are in use, together with a third giving a current of 60 volts and 300 ampères, 200 horse-power being required to drive them. At this works naphtha is becoming more and more used as fuel for the furnaces, 20 forges and 20 heating furnaces being now heated by it, as well as cupolas.

In the out-turn of malleable iron and steel, too, the Ural occupies a prominent position, and the author describes the various exhibits. Chrome iron ore is used for neutral bottoms in the open-hearths, and neutral or acid linings are more generally used than basic bottoms. The chrome ore used contains about 50 per cent. of chromic oxide. The total annual output of chrome iron ore in this district amounts to about 18,000 tons. The open-hearths in use are mostly of from 8 to 12 tons capacity.

XIII.—*SPAIN.*

Fuel Production.—The production of coal and brown coal in Spain in 1895 was as follows in each of the different provinces: *—

Province.	Coal.	
	1895.	1894.
	Tons.	Tons.
Asturias	1,031,240	974,952
Cordova	283,600	268,221
Palencia	142,970	152,563
Ciudad Real	117,000	102,296
Seville	107,500	80,466
Leon	50,000	36,186
Gerona	42,000	44,390
Burgos and Logroño	250	200
Totals	1,774,560	1,659,274

The output of brown coal was as follows:—

Province.	Brown Coal.	
	1895.	1894.
	Tons.	Tons.
Balearic Islands	20,000	21,743
Barcelona	11,000	10,535
Guipúzcoa	9,000	9,166
Lérida	4,000	4,383
Santander	...	809
Teruel	...	739
Other provinces	1,000	1,085
Totals	45,000	48,640

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 222.

XIV.—*SWEDEN.*

Mineral Statistics.*—The condition of the Swedish iron and steel industries in 1894 and 1895 is shown by the following official statistics:—

	1894.	1895.
	Metric Tons.	Metric Tons.
Iron ore	1,927,212	1,904,662
Pig iron, all made with charcoal	462,809	462,930
Blooms produced from pig iron in charcoal hearths	204,517	188,726
Bessemer ingots and castings	83,322	97,320
Open-hearth ingots and castings	84,003	99,259
Crucible ingots and castings	510	598
Blister steel	905	653
Reheated blooms and billets, exported as such	8,083	168,270
Bar iron and steel	146,786	104,206
Nail- and wire-rods, band iron and steel	103,856	15,055
Rails	3,644	12,028
Other shaped iron and steel in bars	8,324	...
Plates (sheets not included)	18,850	...
Number of blast-furnaces in blast	145	146
Total time for all furnaces in blast, days	37,235	36,773
Average daily product per furnace, tons	12·43	12·58
Average time per furnace in blast, days	257	252

The exports of iron and steel from Sweden were as follows:—

	1894.	1895.
	Metric Tons.	Metric Tons.
Iron ores	831,395	800,452
Pig iron	67,026	86,368
Blooms	11,121	16,659
Ingots	5,042	7,381
Bar iron and steel (all kinds except wire-rods)	150,270	177,086
Bar-ends	3,695	5,425
Wire-rods	1,782	3,734
Plates and sheets	3,141	3,869
Nails	2,368	2,701

The imports of iron and steel to Sweden were as follows:—

	1894.	1895.
	Metric Tons.	Metric Tons.
Pig iron for casting	27,679	30,960
Rails	21,665	15,253
T- and angle-bars, &c.	7,865	8,002
Plates and sheets	991	1,438
Tinplates	2,819	2,954
Nails	1,698	1,928

* Kindly communicated by R. Åkerman, Director-General of the Swedish Board of Trade, Honorary Member of the Iron and Steel Institute.

Exports of Iron Ore from Luleå.—In the year 1895 the exports of iron ore from Luleå, Sweden, were as follows:—

To	Metric Tons.
Germany	70,575
Holland	218,845
United Kingdom	74,837
Belgium	16,950
France	2,300
Finland	500
Total	384,007

The ore sent to Holland subsequently goes to Germany.*

XV.—*TURKEY.*

Mineral Resources.—W. May † describes the mining laws of Turkey, and gives a list of mining concessions which have been recently granted in that country. Altogether, there have been granted concessions for the mining of most important minerals, and these the author classifies by provinces. The only true coal in Turkey is mined in a very primitive way, and occurs in the basin of Eregli (Heraklea), on the Black Sea. About 150,000 tons are raised annually, and this is supplied to the Turkish fleet. In an editorial note attached to the paper, it is stated that so badly is the coal mined, that that put on the market often contains 20 per cent. of slate. Gas coke is made at the three gas-works, those at Indikule, Dolmabagt, and Kadiköi. English coke, to the extent of some 400 tons a year, is used by the few small foundries. The total quantity of coal exported from the United Kingdom to Constantinople in 1893 was 461,132 tons. Of manganese ore about 15,000 tons is produced annually, while some 20,000 tons of chrome ore is also raised. This latter contains from 48 to 56 per cent. of chromium. The total quantity of iron imported, mostly from Sweden, amounts to some 25,000 tons, and of steel, mostly from Austria, to 455 tons.

XVI.—*THE UNITED STATES.*

Iron Trade Statistics.—The statistics published by the American Iron and Steel Association ‡ show that the total production of pig iron

* *Deutsches Handelsarchiv*, 1896, p. 385.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 223–227.
‡ *Bulletin of the American Iron and Steel Association*, vol. xxx. p. 165.

in the United States during the first half of 1896 amounted to 4,976,236 tons. Arranged according to the fuel used, the production was as follows:—

	Tons.
Anthracite	684,011
Charcoal	136,697
Bituminous	4,155,528

Discussing the thirteenth edition of Swank's "Directory to the Iron and Steel Works of the United States," *Stahl und Eisen** observes that it is interesting to note that while the first volume, for the year 1876, gave the total number of blast-furnaces in the United States at 713, with a total annual capacity of 4,934,158 tons; in 1892 these numbers were respectively 569 and 14,783,519; in 1894, 519 and 16,431,363; and now there are only 469 blast-furnaces, but these have the annual capacity of 17,651,615 tons. That is to say, while the number of the furnaces has considerably fallen off, the average capacity of a furnace has increased from 6920 tons to 37,636 tons.

There are 44 Bessemer steel-works, with 99 converters, with an annual capacity of 9,623,907 tons; 88 open-hearth steel-works, with an annual capacity of 2,469,337 tons; and steel castings are made in 28 works from open-hearth furnaces. It is impossible to state exactly how much of the steel made is produced by the basic and how much by the acid processes, but it is believed to be about half and half. No basic steel, however, is made by the Bessemer process. There are 45 crucible steel-works, with a capacity of 100,279 tons, and 23 works making iron by the direct process. Of the hundreds of Catalan forges which were formerly at work in the Southern United States there is now but one left—at Crumpler, North Carolina—but seven are at work in the State of New York.† Other statistics are also given.

Tin Plate Manufacture.—In Pennsylvania, in the year 1895, there were eleven tin plate plants, which make their own black plates, one of which did not tin the plates, and there are 19 plants which bought the plates for tinning. The latter possessed 90 tinning sets, and the former 66 hot mills. In addition, 3 black plate plants with 11 hot mills were being built. In the ten black plate plants at work 49,502,700 lbs. of tin and terne plates were made, besides

* Vol. xvi. pp. 315–317.

† See *Journal of the Iron and Steel Institute*, 1896, No. I. p. 432.

63,615,360 lbs. of black plate sold untinned, and 2574 persons were employed. In 17 working plants making tin plates, 557 persons were employed, and the out-turn was 54,873,636 lbs.*

Coke Production.—J. D. Weeks † states that in 1895 there were 295 establishments, with 45,565 ovens producing coke. The average yield of the coal was 64 per cent., and the total out-turn 13,333,714 short tons (of 2000 lbs.), at an average price of 1·44 dollar per ton. In the previous year, 1894, the production amounted to 9,203,632 tons; in 1893, to 9,477,580; and in 1892, to 12,010,829 tons. Pennsylvania maintains its supremacy as a coke-producing State, its out-turn for 1895 being 9,404,215 short tons. Alabama and West Virginia follow with 1,444,339 and 1,285,206 short tons. No other State produces more than half a million tons.

Petroleum and Natural Gas.—J. D. Weeks ‡ states that the most notable features in connection with the production of crude petroleum for 1895 are the great increase in production, especially in Ohio, Indiana, and California; the decrease in the stocks; the rise in prices; and the extension southwards of the profitable producing districts in the Appalachian range. The total production in the United States increased from 49,344,516 barrels in 1894, to 52,983,526 barrels in 1895.

J. D. Weeks § also deals with the production of natural gas in the United States. The year 1895 has seen further decreases in the pressure of the gas, its yield, and in the life of the wells. The value of the gas consumed during the last three years has been as follows:—

Year.	Value in Dollars.
1893	14,346,250
1894	13,954,400
1895	13,006,650

The price has increased, so that the decrease in the out-turn is greater than is shown by the figures.

* "Report of the Bureau of Industrial Statistics through the *American Manufacturer*," vol. lix. pp. 10–11.

† "Sixteenth Annual Report of the United States Geological Survey," Part IV., pp. 218–304.

‡ *Ibid.*, Part IV., pp. 315–429.

§ *American Manufacturer*, vol. lix. pp. 50–51, 85.

XVII.—*COMPARATIVE TABLES.*

The World's Production of Coal and Iron.—For the purposes of comparison, the following summary of the production of coal in the principal countries of the world is appended:—

Country.	Year.	Production in Tons.
United Kingdom	1895	189,661,362
Australia—		
New South Wales	1895	3,738,589
New Zealand	1895	740,827
Queensland	1894	270,706
Tasmania	1894	30,922
Victoria	1895	194,226
Austria, coal	1895	9,572,952
,, lignite	1894	17,332,538
Hungary, coal	1895	1,068,046
,, lignite	1895	3,517,901
Belgium	1895	20,414,849
Canada	1895	3,512,504
Cape of Good Hope	1894	69,690
France	1894	27,459,137
Germany, coal	1895	79,163,615
,, lignite	1895	24,713,198
India	1895	4,370,000
Italy, lignite	1894	271,294
Japan	1893	3,317,188
Natal	1895	160,115
Russia	1894	7,498,000
Spain	1895	1,774,560
Sweden	1894	399,898
United States	1895	172,426,366

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom	1895	7,703,459
Austria	1894	742,372
Hungary	1894	329,985
Belgium	1895	829,135
Canada	1894	50,166
France	1895	2,005,889
Germany	1895	5,431,007
Italy	1894	10,329
Japan	1893	17,501
Russia	1894	1,300,000
Spain	1895	179,752
Sweden	1895	462,930
United States	1895	9,446,308

Comparative Exports and Imports.—A table has been published * showing the condition of the pig iron trade in the principal iron-producing countries in 1894. The figures are as follows:—

Country.	Production.	Exports.	Imports.
	Tons.	Tons.	Tons.
United Kingdom	7,364,745	2,649,998	296,418
Germany	4,986,003	1,539,527	270,314
United States	6,361,162	88,000	309,290
France	2,077,647	155,610	87,531
Belgium	818,597	441,247	330,000
Austria-Hungary	400,000	52,000	215,000

The Railways of the World.—At the close of the years 1890 and 1894 the following lengths of railways were in operation (1 kilometre = 0·62 mile):—

	Length in Kilometres.		Increase.
	1890.	1894.	1890 to 1894.
			Per Cent.
Europe	223,441	245,300	9·8
America	330,576	364,975	10·4
Asia	33,172	41,970	26·5
Africa	9,791	13,103	33·8
Australia	18,947	22,202	17·2
Totals	615,927	687,550	11·6

The tables † also show the details for each of the years from 1890 to 1894, together with the area and population of the different countries, and the mileage of the railways in each of these, together with their first cost. In Europe the greatest percentage increase in the length of the lines of rails laid has been, Spain with 23·0 per cent., Sweden with 15·1, and Russia with 14·9, excluding Greece, which, with an addition of only 139 kilometres of line, shows a percentage increase of 17·9. Russia laid down 4603 kilometres of railways, France 3307, Austria-Hungary 3023, Germany 2593, and the United Kingdom 1344.

World's Output of Manganese Ores.—In a publication in the Journal of the Russian Minister of Finance,‡ the output of

* *Moniteur des Intérêts Matériels*, vol. xlvi. pp. 2633-2634.
† *Stahl und Eisen*, vol. xvi. pp. 678-682.
‡ *Ibid.*, vol. xvi. p. 693.

manganese ores in the different countries is stated to have been as follows:—

Country.	1891.	1892.	1893.	1894.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Australia	5,279	4,558	5,411	...
Belgium	18,498	16,775	...	...
Bosnia	8,847	7,944	7,403	...
Canada	231	105	126	67
Chili	35,017	50,000	50,000	...
Cuba	22,341	18,000	13,922	...
France	15,343	32,406	39,080	...
Germany	40,335	32,191	40,758	43,702
United Kingdom	9,632	6,175	1,380	1,806
Greece	13,453	11,716	5,250	9,313
Hungary	128	1,304	...	...
Italy	2,429	1,243	810	...
Japan	3,249	5,027	14,169	...
New South Wales	140	16	...	...
New Zealand	1,172	526	...	...
Portugal	...	3,399	...	...
South Australia	861	...	...	...
Spain	6,993	16,910	1,560	...
Sweden	9,079	9,832	7,061	...
United States	23,793	19,425	9,297	11,927

In Russia the output has increased from 60,532 tons in 1885 to 248,000 in 1894. The output of the Caucasus in 1895 was 165,865 tons, as compared with 147,125 tons in 1894.

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